HUMAN PHYSIOLOGY:

,81

DESIGNED FOR

COLLEGES AND THE HIGHER CLASSES IN SCHOOLS,

AND

FOR GENERAL READING.

BY WORTHINGTON HOOKER, M. D.,
PROFESSOR OF THE THEORY AND PRACTICE OF MEDICINE IN YALE COLLEGE;
AUTHOR OF "PHYSICIAN AND PATIENT."

Illustrated by nearly 200 Engravings.

NEW YORK
PUBLISHED BY FARMER, BRACE, & CO.
NO. 4, COURTLANDT-STREET.
1854.

R. H. HOBBS,
Stereotyper, Hartford, Ct.

C. A. ALVORD,
Printer, New York.

12

CONTENTS.

PART I.

PART II.

PART III.

PREFACE.

I HAVE aimed so to write this book, that it shall be fitted both for general reading, and for instruction. It is designed for the family as well as for the school. It seemed desirable that these two objects should be accomplished at the same time, and I have not found them to be at all incompatible. The instruction needed by the family on this subject, differs not from that which is required in the school-room, either in regard to the facts to be communicated, or the manner in which it should be done. No one will question the truth of this, so far as the facts are concerned. But it is true even as to the mode of communicating them. In both cases there need to be clearness in statement, and fullness of illustration. Actual instruction is to be given in both cases, and to minds that are very nearly in the same attitude. I could not, therefore, see the necessity of writing a book on this subject for the people which should differ from one written for the school. Besides, it has seemed to me desirable that there should be a greater community of interest between the school and the family than as yet exists; and this object books equally interesting to both will tend to promote.

It may be proper for me to say a word in relation to the style of the work. I have adopted the style of the lecture-room, because, that while it is not inconsistent with conciseness, it is the more natural mode of instruction, especially when so much reference is made to illustrative figures. It has enabled me also to keep in view more effectually the attitude of the minds I address. I have had my readers before me continually as an imaginary audience. I have avoided technical terms as far as possible. Whenever they are used they are sufficiently explained at the time, so that no glossary is needed. Some points commonly considered hard to be understood are treated of, but I have endeavored to simplify them, by

full illustration, and by a presentation of the truth uncomplicated with speculations and hypotheses. And these points are so introduced, that the mind is prepared by the previous investigation to understand them. I have aimed so to arrange the topics, as to have a preparation constantly going on in the mind of the student, fitting him for the proper understanding of what is to come after. By this natural gradation in the development of the whole subject some of the deep things in Physiology can be made clear, which it would otherwise be impossible for the student to understand. It is proper to state here, that I intend to prepare a work for younger scholars, in which some of the simple points in Physiology will be illustrated. This, by familiarizing their minds with the subject, will fit them for a more thorough understanding of the present work.

Although Physiology is becoming a prominent study in the schools and colleges in some parts of our country, its importance is no where as yet appreciated as it should be. It should be made a regular branch in our Educational System. This has been already done in France. "A competent knowledge," says Carpenter, "of Animal Physiology and Zoology is there required from every candidate for University honors; and men of the highest scientific reputation do not think it beneath them to write elementary books, for the instruction of the beginner."

The importance of Physiology as a study, will appear from various considerations.

Many of the subjects comprised in Physiology have, in the case of most students, been already studied in a different phase, or mode, in other branches. Thus, if the student has attended to the Mechanical Powers in his Natural Philosophy, he finds in the human body the principles of the pulley and the lever illustrated in great variety and perfection. The principles in relation to strength in the form and arrangement of structure he sees exemplified in the frame-work of the body in the most admirable manner. If he has studied Hydraulics, he sees in the body the most perfect, and at the same time the most complicated hydraulic machinery, working incessantly throughout life in the circulation of the blood. The principles of Pneumatics he finds applied in the respiration—those of Optics in the eye—those of Acoustics in the ear—and those of Musical Sounds in the apparatus of the voice. And then, his chemical

knowledge meets with new applications in his observation of the changes and the processes going on in the body.

The relations, then, of Physiology to some of the common branches taught in the higher classes in schools, are of the most intimate character. Physiology, in part, merely extends these branches into a new and interesting field; and the student who has once entered this field recurs to these same branches with a renewed interest. Hydraulics, Pneumatics, Optics, &c., have now a new attraction for him, from this, to him novel, application of their principles. The interest thus awakened in his mind is worth much in itself, aside from the mere addition made to his knowledge. And the interest is enhanced by the consideration, that in the human body he sees the applications of these principles to mechanism that exhibits the skill of perfect wisdom and almighty power.

But there are relations of Physiology to still other studies which should be noticed.

The analogies that exist between the human body and all other living things, in relation to structure and growth, are numerous and striking. Though life is so diverse in its processes and in the forms which we see it evolve in the whole range of animated nature, it in some important respects displays a great similarity, which it is interesting to trace throughout its diversified manifestations. Growth, or nutrition, as you will see in the following pages, is essentially the same in the Plant as it is in the Animal. Botany, therefore, taught as it should be, has quite an intimate relation to Animal Physiology. The Science of Life is, in many respects, one Science; and if, in studying any of its subdivisions, we fail to take this broad view of it, and to trace out the analogies referred to, we lose a large part of the interest of the study. Human Physiology, the subject of study in this book, is but a part of a science which offers to the student wide fields of observation exceedingly diversified and full of interest. This being so, I could not avoid in the following pages making occasional reference to the analogies existing between the phenomena of life as exhibited in the human system, and those which we see in the living world around us. So that as the student proceeds with the study, he will find himself interested in the phenomena of life in whatever form they are presented.

This leads me to say that this study of nature, in its broad common relations and its beautiful and extensive analogies, should be made very prominent in our systems of education. It is the application of the principles of abstract science to the forms, and especially the *living* forms of nature all about us, that gives interest to these principles, and makes us to understand and appreciate them. It is here that we find a very serious defect in the prevalent mode of education, even at the present time, notwithstanding all our improvements. Let us look at it a moment. We live in the midst of a material world, animate and inanimate, and have daily converse, so to speak, with material forms of every variety, presenting phenomena of the highest interest and of endless diversity. And yet, through almost all the period of childhood, and perhaps we may say youth also, this book of nature is in the school-room very nearly a sealed book. The very process of education shuts in the pupil from this broad contemplation of the world in which he lives. He is drilled through spelling, reading, grammar, &c., but he is left in total ignorance of the beautiful flowers, and the majestic trees outside of the school-room. How very few even of thoroughly educated adults, know the processes by which a plant or a tree grows! And the same can be said of other phenomena of nature.

The defect which I have pointed out runs through the whole of education. We can see it even in the prevalent mode of teaching the natural sciences themselves. One would suppose that here the facts, the phenomena, would command the chief attention of the teacher and the student. But it is very commonly not so. The mere technicalities and the classification are made much too prominent. Botany, really one of the most interesting of all branches of natural science, is thus ordinarily made one of the driest of studies. To teach this aright, the phenomena of vegetation, so varied and so beautiful, should constitute the chief material of instruction, and the mere classification should be considered, although necessary, as wholly a secondary thing.

The great facts of the world, both of mind and matter, should furnish really the *material* for education, and those branches that are ordinarily pursued with such assiduity should be considered as merely subsidiary to the teaching of these facts. The whole order of education must be re-

versed. Instead of beginning the child's education with learning to spell and read, the object should be to make him an observer of nature, and the spelling and reading should be done in connection with this, and as subsidiary to it. Things and not words, or mere signs, should from the first, constitute the substantial part of instruction. The child should be made, at home, in the school, and everywhere, a naturalist in the largest sense of that word. We should aim to impart to him a spirit in consonance with the following precept of Hugh Miller, the famous self-taught geologist. "Learn to make a right use of your eyes; the commonest things are worth looking at—even stones and weeds, and the most familiar animals."

As it is now, no one becomes a naturalist early in life, except in spite of the tendencies of his education. The study of nature is not only not encouraged, but is absolutely discouraged in our educational system. If any one, like Hugh Miller, by the force of a taste that can not be repressed by the training of the school-room, undertakes to make a "right use of his eyes," and curiously examines "stones and weeds," he is regarded by the world of spellers and readers and grammarians and cipherers, as a strange genius. But he is pursuing from an irresistible internal force, the very course that I would have every student, even from his childhood, encouraged to pursue, in a measure at least, by the external circumstances of his education. The tendencies of his training should be decidedly in this direction.

If the general mode of education were changed in the manner indicated, education would have much less of the character of mere drudgery than it now has. Not that there would be any the less labor; but the labor would be made lighter by the interest imparted to it—the interest, which always results from the study of facts and phenomena, and never from the learning of mere words and technicalities and classifications. I would gladly dwell on this subject, and show by varied illustrations how the mode of instruction referred to, should be pursued, and especially with younger scholars; but the limits of a preface will not allow me to enter so large a field.

The change which I have pointed out can not be effected at once. It will require time. Confirmed traditional customs are to be done away,

the habits of teachers are to be altered, and the proper books are to a great extent to be yet written, especially such as are fitted for the first years of education.

If the study of nature should be thus made prominent in education, human physiology would be considered altogether its most interesting and important branch, and for several reasons. First: there is no where to be found so curious a collection of mechanisms, or so interesting and wonderful a series of processes, as in the human body. In nothing else in the wide world are the principles of so many departments of science so extensively and perfectly exemplified. Life works here its most complicated set of machinery. Secondly: the singular and mysterious connection of the immaterial and immortal soul with the material and perishable body, gives intense interest to this study. In Physiology we do not study matter alone, or spirit alone, but both matter and spirit united, and often acting together. This circumstance distinguishes this from all other studies. Thirdly: it is *our own* frames, moved by the spirit within us, that we study. The subject has a personal interest for us, that is not presented by most studies, and by none in so large a degree as in this. And Fourthly: the study is of great importance, because a judicious and efficient Hygiene must be based upon a knowledge of the laws of physiology. We cannot know how to keep our functions in the condition of health, without understanding the laws that regulate them. I have said but little in this book in regard to hygiene, and that only incidentally, because that subject would require of itself a whole volume to elucidate it properly.

I have not thought it proper to indulge to any great extent in those reflections, which the contemplation of so perfect and diversified a congeries of mechanisms as are presented in man would naturally suggest, in regard to the skill of the great builder of the universe. Such reflections would extend the book to too great length. Besides, they are so readily suggested to the mind of both teacher and scholar, that it is entirely unnecessary for the author to dwell on them.

I have treated of some subjects, on which, from the difficulty of understanding them, there has been a disposition in many minds to go beyond what we know, and indulge in unwarranted speculation. On these

points I have taken pains to draw the line very distinctly between what is known, and what is supposed. I deem it to be important to prevent the minds of the young from being led away from the simple truths of science by ingenious speculations and plausible reasonings. Let me not be understood to decry all hypothesis. I only object to the mingling of facts and suppositions together in one indiscriminate mass, as is often done. The disposition to do this, which is more common than is generally supposed, exerts so injurious an influence upon the habits of the mind, and so confuses its views of truth, that we ought to look upon it as one of the most serious evils to be guarded against in education. It is really one of the most prominent obstacles to the progress of truth on all subjects, both in individual minds, and in the minds of the community at large. This disposition, so apt to be fostered in the enthusiastic mind of youth, by ingenious but dreamy speculations, should be corrected at the outset, and the mind should in its forming stage, be habituated to the discrimination between the proved, the true, and that which rests on presumptive, perhaps merely plausible evidence. This discrimination should therefore be exemplified in books designed for instruction, and this I have attempted in the present volume.

I have divided the book into Three Parts. The First, which I have made as short as possible, is merely *preliminary* to the consideration of the particular subject of the book. In the Second Part, I present the human structure, simply as a *structure*, and show how it is constructed and kept in repair. In the Third Part, I treat of all those subjects which relate to the *uses* for which the structure is designed. This natural division of the whole subject, not only presents it to the mind of the student in an interesting point of view, but secures that natural gradation in its development, which I have spoken of as being necessary to a clear understanding of its deeper and more intricate portions.

PHYSIOLOGY.

PART FIRST,

CONTAINING,

CHAPTER I.—ORGANIZED AND UNORGANIZED SUBSTANCES. CHAPTER II.—THE DISTINCTION BETWEEN ANIMALS AND PLANTS. CHAPTER III.—MAN IN HIS RELATIONS TO THE THREE KINGDOMS OF NATURE.

CHAPTER I.

ORGANIZED AND UNORGANIZED SUBSTANCES.

1. THE crystal and the plant are both wonderful *growths.* As you look at them, you think of the crystal as having been formed, and of the plant as having grown. But in one sense they have both grown to be what they are. The crystal was once a minute nucleus, and the plant was once a little germ.

2. In one respect they are alike in their growth—both have increased from particles taken from things around them. But the processes by which this is done are different in the two cases. The crystal has increased or grown by layer after layer of particles. There are no spaces or passages by which particles of matter can be introduced inside of it. Any part of it, when once formed, is not altered. It can receive additions upon the *outside* alone. But it is not so with the plant. This enlarges by particles which are introduced into passages and interstices. It grows, as it is expressed, by *absorption* or by *intussusception.*

3. How, now, is this absorption effected? It is done by certain vessels or *organs*, constructed in the root of the plant for this purpose. These take up or absorb fluid matter from the earth. There are other organs which circulate this fluid through all the plant; and others still which use it for the purpose of growth or formation. There are no such organs in the crystal, for it has no *inner* growth. The plant is therefore said to be an *organized* substance or being, and the crystal is an *unorganized* substance. And so we speak of the *organic* structure, or the *organization* of plants.

4. These organs, which thus absorb, and circulate, and construct, do not act simply on *mechanical* principles. The plant is not merely soaked with fluid, which the heat of the sun may expel, as it does water from a porous mineral substance. These organs are active agents, and they perform their duty with a force, and after a manner, for which no mechanical principles can account. No mechanical powers could alone supply the leaves of the mighty tree of the forest with sap from its deep roots; much less could they form these leaves.

5. Neither do these organs act simply on *chemical* principles. While man, through the agency of chemistry, can form some of the crystals which are found in nature, he can not by any arrangement of constituents make a plant, a flower, or a leaf. And the plant, left alone to the action of chemical principles, wilts; and at length ceases to be a plant, and becomes common unorganized matter.

6. Mechanical and chemical principles, it is true, are both employed to some extent in the growth of plants; but they are under the control of other principles, which we term *vital*. And so we speak of the plant not only as an *organized substance*, but as a *living being*.

7. What I have said of plants, in distinction from minerals, may also be said of animals. They are also *organized living* beings, and they have generally a more complex organization than plants, as you will see as I proceed.

8. The whole material world, then, that we see around us, we divide into two parts—the unorganized and lifeless, and the organized and living. The distinctions thus pointed out between organized and unorganized matter are essential and fundamental. But let us look at some other distinctions, which either arise from these or accompany them.

9. One distinction is this. All the parts of the mineral are independent of each other, while it is otherwise with the plant or the animal. Accordingly, we examine the properties of minerals in a different way from those of plants and animals. The chemist can ascertain all the properties of a crystal or a rock, if you give him but a small piece of it. But the botanist can not ascertain all the properties of a plant by looking at some one part of it. If he examine the flower, this gives him no knowledge of the root. In order to know all about the plant, he must examine every part by itself, and then look at it in its relations to the other parts. The same can be said of the physiologist, in his investigation of the properties of animals.

Assimilation in organized substances.

10. As the crystal is forming by layer after layer of particles, no change is effected in these particles as they are becoming arranged in the layers. But in the case of the living organized being, a change is produced in the particles which are taken up by the absorbents. And the change, ordinarily, is both a gradual and a complex one. In the plant, a change is produced in the particles in the very act of absorption; but this change is only the beginning of a process which is afterwards perfected. The sap is not thoroughly fitted for nutrition when it first begins to circulate. It is carried up through the vessels of the trunk or stalk to the leaves. There the last step of the process is taken, and the sap is now ready to be used in the growth of the plant or tree. So, also, in the animal, the nutritious part of the food, taken up by the absorbents in the digestive organs, is first acted upon by certain little glands, through which it passes, is then poured into the circulation, to be mingled with the blood, and is carried with the blood to the lungs, to be exposed to the air; and thus it is fitted for the nutrition or growth of the body. This process, which is thus carried on in the plant and in the animal, is very properly called *assimilation*. For the particles that are taken up by the absorbents in the root of the plant are, by this process, made *like* to the plant; and the particles taken up by the absorbents in the stomach * are made *like* to the animal. So obvious is this, in the case of the animal, that some French physiologist speaks of the blood as *chair coulante*, or running flesh.

11. Another prominent distinction between organized and unorganized substances is in relation to *permanency*. Constant change appears in all organized bodies; while permanency is written upon all substances which are unorganized. In organized beings, continual change is going on at every point. It is a condition of their being. This is true, not only of the decline of a plant or animal, but even of its growth. For, in its growth, as the parts enlarge internally as well as externally, they change not only the arrangement of the particles, but, to a great extent, they change the particles themselves. It is

* The word stomach requires some little explanation, as it is used in physiology in two senses—in a limited sense, and also in an extended one. It is used in its limited sense, as referring to the cavity at the beginning of the *alimentary canal*, as it is termed; this latter term being applied to the series of cavities, the stomach and the small and large intestines, which are found in the digestive apparatus in the higher orders of animals. In comparisons, however, between these animals and those which have a more simple digestive apparatus, the word stomach is used in a more extended sense, as being synonymous with the term alimentary canal. It is used in this sense, also, when, as in the present case, it is referred to in a comparison between animals and vegetables.

true, as well of the towering tree as of the tiny plant, that these changes have been going on during all its growth; so that, at its maturity, it is, both in relation to the arrangement of its particles, and in relation to the particles themselves, a very different thing from what it was when it pushed its germ up through the ground, or even when it was but a small tree. Not only has it received into its interstices and passages new particles, but it has thrown off from the pores of its leaves, those outlets for the refuse of plants, vast quantities of particles which are no longer of use in its structure. So, in all animals, the same internal changes are going on, and to a much greater extent; because, from the activity of their nature, there is more of wear and tear, and, therefore, more of refuse matter to be disposed of. As you will see in another part of this book, the human body, that most complicated of organized beings, undergoes these changes very largely.

12. It is not thus with unorganized substances. The crystal, so fast as it is formed, becomes permanent. No changes occur *within* it. In itself, it is unchangeable. It can not change its own particles, as the plant or the animal does. It can be changed only by external addition, or by external diminution, through the influence of agents acting upon its surface.

13. With the constant changes going on in organic nature, there is constant succession. Plants and animals produce other plants and animals, and themselves die, making room for their successors. But the crystal does not form other crystals, and then crumble into dust. In itself, it is both *unchangeable* and *unproductive.*

14. This distinction between organized and unorganized substances, in relation to change and succession, meets the eye everywhere. The mountains, the rocks, and even the stones under our feet, remain the same year after year, while all vegetable and animal life is ever changing its forms and manifestations. There are the changes of growth, and the changes of decay and death, all around and within us; and they are strangely mingled together. There is death even in the changes of life, as the waste particles are taken away, and are replaced by the new; and life springs out of the very bosom of death, as from decayed nature new forms of vigor and beauty arise. The mountains stand as they have stood, as the passing generations have looked upon them, while the continual changes of vegetation have been going on upon and around them. The seasons crown their battlements with the emblems

of their ever-returning mutations of life, decay, and death; and even the mighty trees, that have shed their leaves from year to year, in obedience to the great law of change, but have themselves stood, at length bow their heads to the same law, and give place to other lords of the forest. From the "everlasting hills," which thus remain the same, though change is ever about and upon them, man gets the unchangeable and imperishable rock to construct his habitation, while he himself is changeable and perishable—the creature of a day, whose life is as a vapor. He wears the precious stones, and traffics in the golden ores, which have existed from the creation of the world, through all the changing and dying generations, and passes away, leaving them to others as changeable and perishable as himself.

15. Another distinction between organized and unorganized substances relates to the forms which they assume. There is regularity in both, but it is different in each. Unorganized matter is disposed to arrange its particles in straight lines, and with angles mathematically exact. You see this in the beautiful crystal; and you also see it, less definitely, but magnificently, displayed in the regular battlements and columns of rocks and mountains. The tendency is to regularity; and irregularity is the result of interfering circumstances. A similar disposition to regularity is manifest in organized substances, but in a different manner. It is disposed to curved, rather than straight lines, and seldom makes lines or angles with mathematical exactness. We see this law of regularity exemplified both in animal and vegetable life. The leaf, for example, has the same general shape, that is, the same general arrangement of particles, when it attains its full size, that it had when it was small; and the same can be said of the arm of the man, compared with his arm when a child. Illustrations might be cited to any extent, but these are sufficient.

16. While the law of regularity is not commonly as exact in organized substances as it is in the unorganized, it is quite as authoritative. While it does not ordinarily observe the perfectly straight lines and the unvarying angles which we always find in the crystal, the general plan and contour are very strictly preserved amid all the changes of animal and vegetable life. And, in some cases, the same mathematical exactness that we find in the mineral world is found in organized beings. I know not that this is ever true of straight lines and angles; but it is often true of curved lines. There are many very

beautiful examples in the vegetable world. I will give but a single one. If you look at the common white daisy, before the hundreds of little buds in its bosom have opened into tiny flowers, you will see them arranged with great exactness in crossing curved lines, such as you often see on the back of a watch case. A similar arrangement you will find in many flowers.

17. This regularity is more wonderful in organized substances than in the unorganized, because it rules in them in the midst of constant change. In the case of the crystal, as there are no internal changes in it, and as each layer of it, when formed, is permanent, regularity is comparatively, so to speak, easily secured. But in the case of the leaf, as it is growing to its full size, and of the arm, as it grows from infancy to be the stalwart arm of manhood, continual change is going on at every point; and regularity here is obviously a more difficult achievement.

18. This regularity appears still more wonderful, when we look at the infinite variety of forms in organized matter, in both the vegetable and the animal world. In all these forms, each part of every animal and of every plant maintains its own peculiar plan and contour. Take, for example, the leaf in its endless varieties. How definitely does each variety preserve its individual character, and how easily is it distinguished from every other variety! The same can be said of every part of every organized being.

19. Another circumstance still must be mentioned, as adding to the wonderfulness of this regularity. It has been scrupulously maintained, through all the changes of the world from its creation, when God pronounced the works of his hands to be "very good." The leaf of every tree, for example, is like the leaf of its ancestral trees back to that time; and so it will be in all its successors to the end of the world. "The trees of the garden," which delighted the eyes of our first parents, and refreshed them with their shade in their innocence, and amid which they hid themselves after their sin from the presence of their Maker, undoubtedly had the same characteristic shapes, and the same leaves and flowers which their successors present to our eyes.

20. Again, it is interesting to notice that, in the midst of this regularity, so strictly maintained in each specific form from age to age, there is a measure of irregularity allowed. While each kind of tree, for example, has specific characteristics in

the arrangements of branches and other parts, and in the shapes of its leaves, no two trees of the same kind are exactly alike, and there is always much variety in the leaves of the same kind. The wonder is, that so much latitude is allowed in this respect, and yet the specific characteristics of each kind are so thoroughly preserved. We can readily see that if a pattern, definite in all its details, were to be copied exactly in each kind of vegetable and animal form, the distinctions between them could be more easily preserved. But Omnipotence is able to combine a wide latitude and variety of form in each kind, with a strict and uniform preservation of its characteristic contour and arrangement. We have a striking exemplification of the above remarks in the variety of the human countenance. While the face of man is so entirely different from the face of every other animal, at the same time, among the hundreds of millions of the human family, how uncommon it is to find two faces that are very nearly alike.

21. In the animal world, we see remarkable examples of the preservation of regularity of form in the exact correspondence which exists so commonly between the two halves of the body. For example, the brain has two halves, which are precisely alike, and the same is true of the nerves which are distributed from it. And so of other parts. But, mingled with this symmetrical arrangement of parts, there are other parts which are irregular in their shape. This is the case with the stomach, the heart, the liver, &c. There are some animals which are altogether destitute of this arrrangement of two similar halves of the body. The oyster is a familiar example. The shell of this animal is strikingly in contrast, in this respect, with the shells of some other of the bivalve tribe, as, for instance, the common clam.

22. There is a distinction between organized and unorganized substances, in regard to *size*, which must not pass unnoticed in this connection. The size of unorganized bodies has no fixed limit. A crystal or a rock may grow to any imaginable size, if the particles forming it are sufficiently abundant. But organized bodies have limits fixed to their growth. There is, it is true, more or less latitude to these limits; but they are so well defined in the case of most vegetables and animals, that when growth reaches much beyond or below the limit, it is recognized as a remarkable fact. Gigantic and dwarfish varieties are rare exceptions to the general rule.

23. The last distinction, between organized and unorganized

substances, which I shall mention relates to their *structure.* While unorganized substances are made of one form of matter, either solid or liquid, or gaseous, organized bodies are made of a mixture of fluids and solids. They are therefore more or less soft and flexible; while the solid, unorganized substances are hard and brittle. There is a still further difference in structure. Organized substances are much more compound than the unorganized. Most of the unorganized substances are composed of only two or three elements. Thus, air is composed of oxygen and nitrogen, water of oxygen and hydrogen; and most of the mineral salts are composed of three elements—as, for example, carbonate of lime, or chalk, which is composed of oxygen, carbon, and calcium, the mineral base of lime. But organized substances are composed of at least three or four elements, and sometimes more. The four principal elements in the composition of organized bodies are, oxygen, nitrogen, hydrogen, and carbon. But there are other elements introduced for special purposes. Thus, carbonate of lime (a combination of calcium with two of the common elements, carbon and oxygen,) is diffused very generally throughout the textures of plants, giving them firmness and strength. In the grass tribe, silex is deposited under the surface, producing the necessary combination of strength and lightness, a very small quantity of the silex answering the purpose. In animals of the higher orders, phosphate and carbonate of lime compose in part the framework of the body. We find iron, too, in the blood. Of the fifty-four elementary substances discovered in mineral bodies, only eighteen or nineteen have been found in plants and animals, and some of these in very small amounts. The *essential* components of living substances are the four *non-metallic* elements mentioned above—oxygen, hydrogen, nitrogen, and carbon; while the bulk of the inorganic world is composed of the metals and their compounds, viz., the alkalies and the earths. And it is interesting to observe that, of the four elements which compose the bulk of the animal and vegetable world, both the fluids and the solids, three are gaseous, while but one, carbon, is a solid substance.

CHAPTER II.

THE DISTINCTIONS BETWEEN ANIMALS AND PLANTS.

24. Having pointed out in the first chapter the distinctions between organized and unorganized substances, I now proceed to consider the distinctions between the two classes of organized beings—animals and vegetables. I shall first notice those differences which are obvious when we look at the great majority of animals and vegetables; and shall then point out those which are *essential*, in order that we may have a clearer view of those exceptional cases, in regard to which it is somewhat difficult to decide to which of the two kingdoms they belong.

25. One of the most obvious distinctions is in relation to *locomotion*. The plant remains in one place; while the animal moves about, in the air, or in the water, or upon the surface of the earth. And the structures of the animal and the plant of course differ, so as to accommodate these two very different modes of existence. I will particularize. As the animal moves from place to place, it must, for this reason, if for no other, have an apparatus of nourishment and growth different from that of the plant. The plant, by means of its absorbents in the roots, takes up from the earth, in the form of sap, its nutrition, or food, as it may very properly be called. The moving about of the animal would in itself forbid its deriving its food directly from the earth, even if the earth contained the proper materials for its nourishment. Another contrivance must therefore be resorted to, in order to effect nutrition in its case. So a cavity is provided in its body, called a stomach, into which nutritious substances can be introduced. And this cavity is lined with absorbents, which there do for the animal just what the absorbents in the roots of the plant do for the plant.

26. Besides the stomach, there are other great central organs which are peculiar to most animals, in distinction from vegetables—as the heart, the liver, the lungs, &c. In the plant, there are no such central organs upon which the whole plant depends. Branches and roots may be cut off extensively, and even a large portion of the stem or trunk may be destroyed; and yet what remains of the plant may still live. And

even more than this. A small portion of it may be made to take root and live by itself. It is not so with most animals. Mutilation can not be carried far without injuring some large organ which is essential to the life of the whole; and no part taken from its extremities can be made in any way to live by itself.

27. Another obvious distinction is this. Animals are *sentient* and *spontaneously-moving* beings, while vegetables are not. The animal *feels* the action of agents upon it, and this it can not do without consciousness and thought. The evidences of the existence of consciousness and thought, and the consequent spontaneous motion, are very slight in some animals. Still, there is no doubt of their existence in these cases. We see these evidences plainly in the great majority of animals; and we infer, very properly, the existence of sensation and thought in those exceptional cases, where the evidences are doubtful or absent, as we find in them other marks of animal in distinction from vegetable life.

28. The distinctions which I have mentioned are those which we see generally existing. Let us see how far they are essential and universal.

29. The distinction in regard to locomotion, if we look at the animal as a whole, has its exceptions. There are some animals that are entirely confined to one spot during all their existence, as the coral animal and the sponge. But, while some animals are thus confined, they have the power of spontaneous motion in some of their parts, which is exercised for the purpose of obtaining food, and, in some cases, for the avoidance of danger. This power is not possessed by any plant. Some few plants, as the sensitive plant and the venus catch-fly, (dionæa muscipula,) exhibit a property which resembles it, but it is essentially a different thing. In these cases, the influence of the stimulus that excites the motion is communicated from particle to particle, from the point where the stimulus is applied; and the motion is only in one direction, and not in various directions, as is the case with spontaneous animal motions. This can be very readily seen, if we compare the motion of the sensitive plant or the catch-fly with those of the little fresh-water polype, called the Hydra. This animal, of which I give you here an enlarged representation, and also a representation of its natural size, is found in ponds. It attaches itself to any floating object—a stick or straw, as seen in the Figure—by a kind of sucker. Thus supporting itself, it stretches out its long

arms, to take for its food any minute worm or insect which may float within their reach. When it catches one, it directs it to the mouth, *a*, which opens into the stomach or general cavity. Now, in doing all this, there is a variety, a compound character in the motion, which is in plain contrast with the simple motion of the leaves of the catch-fly and the sensitive plant.

FIG. 1.

HYDRA.

30. The distinction, in relation to a digestive cavity, can not be made out in the case of some of the lower animals. And, if it could be, it is not an *essential* distinction. For it only relates to a mere difference of arrangement in the absorbents that take up the nutritious substance in the two cases. The absorbents in the stomach of the animal, as before remarked, perform the same office that the absorbents do in the root of the plant. They only do it in a different place, and after a different manner. The same remarks, substantially, can be made in regard to the other large central organs which are found in most animals.

31. The last of the distinctions, which I mentioned as being commonly observed, is really the essential distinction between plants and animals. I mean the capacity for sensation and spontaneous motion, which exists only in the animal. There is nothing truly analogous to this in the plant. And we, accordingly, find a peculiar structure in animals, devoted to these functions, and others connected with them. This structure is the nervous system. No trace of such a structure has ever been discovered in any plant. If there were any true analogy between animal motion and the motions of the sensitive plant and the catch-fly, we should be able to find in them traces of nervous structure; for the structure of these plants is so plainly developed, that its constituent parts are easily distinguished.

32. The nervous system is evidently not essential to nutrition, for this is as well effected in the plant as in the animal.

This is accomplished in both in substantially the same way. The means by which it is done, and its arrangements are modified, as you have seen, in the two cases, to suit the differing circumstances. The nervous system, observe, then, is, for particular purposes, superadded in the animal to what is common both to the animal and the plant, and so constitutes the essential difference between them. And so, all the functions relating to nutrition, which are of course common to plants and animals, are called functions of *organic* life. But the functions which are performed by the system superadded in the animal, the chief of which are sensation and spontaneous motion, are termed functions of *animal* life. These are sometimes also called functions of *relation*, from the especial connection which they form between the animal and all that is around him.

33. These animal functions, sensation and spontaneous motion, imply thought and will. The order of action is this: sensation—thought in regard to it—action of the will in consequence of thought—then, from this action, an impression carried through nerves to organs termed muscles—motion in them from their contraction. This order, however, is not always observed. The first link, sensation, may be absent. Thought, without any preceding sensation, may prompt the will, and spontaneous motion results. The action of the will, too, may be left out, or may be in opposition. Thus, emotions may produce action of the muscles, the will not concurring, and perhaps opposing; as when we laugh at what is ridiculous, or weep at what is sad, in spite of restraining efforts dictated by the will.

34. There are also instinctive motions, and motions which are termed automatic, with which the will has no direct connection. And the connection of sensation with them is, in some cases at least, doubtful. The action of the muscles, in swallowing, breathing, &c., and the action of that compound muscle, the heart, are examples of motions more or less disconnected from the will, and also from sensation. The action of the heart is wholly removed from the direct influence of the will, and it is at least not obvious that it is influenced directly by sensation. It is influenced indirectly by both, through the agency of emotions awakened by them. The muscles of breathing, on the other hand, though ordinarily involuntary, may be directly influenced both by the will and by sensation. You can at will breathe faster and more deeply, and sensations of uneasiness in the chest modify the breathing.

35. For all these different actions, thus produced in different ways, there are central parts of the nervous system upon which the causes of these actions produce the impressions or impulses from which the actions result. Thus, when a sensation is followed by a spontaneous action of muscles, an impression is conveyed by nerves to the central organ; the will there acts, and the impulse there given by this action of the will is carried by other nerves to the muscles, which execute the intended movement.

36. These central parts or organs, which are the media, the instruments of impressions, are in different parts of the body of the animal; but the most important of them is what we call the brain. This part is developed most in those animals that give the greatest evidences of intelligence; and, therefore, it is more prominent in man than in any other animal.

37. It may be remarked, as a general truth, that the nervous system, and its associate or subordinate system, the muscular, are developed in different degrees or forms, to suit the different characters and wants of animals. In man, they are more complex and perfect than in any other animal. The brain, in him, is a large organ, occupying the skull. The spinal marrow, and other central parts, and the nerves, are largely developed. And the muscles which are moved by this nervous system form a large portion of the bulk of the body. The organs of nutrition, analogous to those which make up nearly the whole of the plant, occupy the two cavities of the trunk of the body, the thoracic and the abdominal. But, as we descend in the animal kingdom, the nervous system becomes continually less prominent, and the system of mere nutrition more so. We at length come to animals, in which the nervous system is a mere small appendage to the system of nutrition, and only serves to direct the muscles in securing the food of the animal. In some of these, we not only do not find a brain, but we fail to discover any traces of a nervous system. This is true of the Hydra, noticed in § 29.

38. The nervous system, which so clearly distinguishes most animals from all plants, is fairly presumed to exist, though in an exceedingly slight degree, in those beings in which it can not be found, but in which we find other characteristics of the animal kingdom. And it is presumed, also, that the exercise of thought and the action of the will, which most animals so plainly exhibit, while they become less and less obvious as we descend in the scale, are not wholly obliterated in the very

lowest animals. It may, perhaps, be said, that as muscular action, as mentioned in § 34, is sometimes produced even in man without the intervention of thought or the will, it may be produced in animals of the lowest order altogether in this way. But we may more rationally infer that, as the chief object of motion in them is the securing of food, it is guided by the action of a will in obedience to their sensations. In other words, it is truly a spontaneous, and not a mere automatic motion. And it is probable that there is in the very lowest of animals some degree, though it may indeed be slight, of enjoyment in the sensations received from the moving water about it, and from the satisfying of its wants in the process of nutrition. We will take the Hydra, a representation of which is given in Fig. 1, page 23, as an illustration of the above remarks. It is a minute gelatinous animal, in which no nervous or muscular fibres can be found. And yet it has an extraordinary power of extending and contracting itself. When it is alarmed, it draws in its arms, and shrinks into the form of a little globule; and if you should see it in this condition, you would not suspect that it had any arms or tentacula. But when it is searching for food, it often extends its body and its arms to a great length; and when it grasps its prey, it puts it into its stomach, which constitutes, so far as we can see, its whole body. We can not conceive of all these motions, thus executed to effect certain definite objects, without the agency of a will, and without sensations to prompt the will and guide the motions. The animal must have a power of choice, or it would put a bit of stick or straw into its stomach as readily as a worm or an insect. But the tentacula never grasp, among the various bits of things which float against them, any thing beside the appropriate food of the animal. And it undoubtedly enjoys its food as really, though perhaps not as vividly, as any human epicure; and has in some measure the same pleasurable sensations which locomotion produces in us, as it floats along so quietly, with its arms hanging down from its body. Though there be no nervous fibres to be seen in the loose gelatinous structure of this little creature, yet, as the phenomena which it exhibits are known to be produced by the nervous system in those animals whose structure is more plainly and thoroughly developed, we justly infer that there must be nervous matter, in some form, in this and other similar animals.

39. One more important distinction between animals and

plants remains to be noticed. It relates to their chemical composition. I stated, in § 23, that organized substances are composed mostly of four elements—oxygen, hydrogen, nitrogen, and carbon. Plants differ from animals, in having but little nitrogen in their composition. It was formerly supposed that they contained none of this element. It is found only in particular parts of plants, as the seeds. We may regard carbon as the most characteristic constituent of vegetables, and nitrogen of animals. And in this connection it is interesting to observe that, while carbon is largely thrown off from the lungs of animals, in the shape of carbonic-acid gas, it is as largely absorbed by the leaves of plants. Of this fact I shall take more particular notice when I come to the subject of respiration.

CHAPTER III.

MAN IN HIS RELATIONS TO THE THREE KINGDOMS OF NATURE.

40. MAN is commonly spoken of as being at the head of the animal kingdom, and in the book of the naturalist is made an order of the class termed Mammalia. As the basis of the whole classification is mere material organization, and has no reference at all to mental or spiritual endowments, the classification, in regard to man, is in its principle correct. At the same time, it must be admitted, that it fails to recognize altogether the *essential* distinctions between man and other animals. These distinctions, making, as they do, a wide gap—"an impassable chasm," as Professor Guyot expresses it—between man and the inferior animals, are to be found in certain peculiar spiritual endowments which man possesses. These I will notice now in the briefest manner, leaving it for another part of this book to treat more fully of this and other kindred subjects. One of these endowments is the power of *abstract reasoning.* Other animals in a certain sense reason, that is, they make inferences; but they never arrive at any general or abstract truths. Another endowment is a moral one, linking man in his spiritual nature to the Deity. It is *conscience*, or the knowledge and sense of what is right, in distinction from what is wrong. Other animals, in obedience to the passions of fear and love,

sometimes appear to the superficial observer to have an idea of what is right, as such; but there is not the slightest evidence that they really have any such knowledge.

41. In view of these endowments of man, it is wrong to consider him merely as being at the head of the animal kingdom. He is something more than this. He is so much and so distinctly more, that the accepted classification of him, on the ground of mere difference of organization, gives a most inadequate idea of his true position in the scale of being. It leaves entirely out of view the *essential* distinctions; and it separates man from other animals, as you will see, by a distinction of organization which is of rather a trivial, perhaps questionable, character.

42. The force of this view of the subject is enhanced, if we take into consideration that great fact, revealed to us by God in his Word, that man is destined to *immortality*. It may be objected that, as this fact is learned only by revelation, and not by observation, it is not to be regarded as a scientific fact. But, granting that there is truth in the objection, it certainly is allowable to allude to the revelations of Scripture, as confirming or enforcing views developed by scientific observation. This is all that I have done in this case. The view which I have presented is based upon endowments that are recognized by the scientific observer, without the aid of revelation; and I appeal to the revealed fact of man's immortality, as adding force to this view, and not as being at all necessary to the establishment of its truth.

43. Let us look at this subject in another point of view. The grand essential distinction between animals and plants lies, as you have seen in the last chapter, in the fact that animals have a nervous system. Now, with this system, as you have also seen, appear certain mental manifestations. These differ widely in different animals, and are most prominent in those in which this system is most prominent and complicated. As we trace upward these complications, when we come to man, we find certain mental manifestations, which separate him by "an impassable chasm" from all other animals. Till we arrive at him, the difference is one of *degree*, for the most part. But in his case it is a difference of *kind*, and a very wide one. Of such a difference the naturalist should certainly take very distinct cognizance; and, if it be not consistent for him to do so in his classification, great force and prominence should be given to these views in his instructions on this subject. As the super-

adding of the nervous system separates the animal from the plant, so, also, as Professor Guyot very justly maintains, the superadding of such endowments as we find in man separates him, by a chasm quite as "impassable," from other animals.

44. The distinction commonly received as the ground of classification for man, I have said, is a trivial, perhaps a questionable one. He is said to have two hands, and so makes the order Bimana; while apes and monkeys are said to have four hands, and are, therefore, considered as making the order Quadrumana. Now, if we observe carefully and fully the wonderful endowments of the human hand, we shall hardly be willing to allow that monkeys and apes have four such members. With a full view of the capabilities of the human hand, those members can not be considered as hands, but as members possessing some of the properties of both hands and feet. They are given to these animals to enable them to climb with facility, and to grasp their food; and they have none of that infinite variety of motion, which is so striking a peculiarity of the hand of intelligent man. The ground upon which they are said to have four hands is that which is thus stated by Cuvier. "That which constitutes the *hand*, properly so called, is the faculty of opposing the thumb to the other fingers, so as to seize upon the most minute objects." No animal besides man has this arrangement, except the Quadrumana. It is claimed, therefore, that they have hands, although they are very imperfect when compared with the hand of man. The imperfection is indeed so great, as to make us at least reluctant to admit the claim set up by the naturalist. "While," says Carpenter, "the thumb in the human hand can be brought into exact opposition to the extremities of all the fingers, whether singly or in combination, in those Quadrumana which most nearly approach man, the thumb is so short, and the fingers so much elongated, that their tips can scarcely be brought into opposition, and the thumb and fingers are so weak, that they can never be opposed to each other with any degree of force. Hence, although admirably adapted for clinging round bodies of a certain size, such as the small branches of trees, &c., the extremities of the Quadrumana can never seize any minute object with such precision, nor support large ones with such firmness, as are essential to the dexterous performance of operations for which the hand is admirably adapted." Indeed, what is called the thumb of the Quadrumana is so short and slender, that Eustachius, the anatomist, very properly said that, regarded as an

imitation of the thumb of man, it is a ridiculous affair. If, then, we take into view the extensive and varied capabilities of the human hand, we must agree with Sir Charles Bell, when he says that "we ought to define the hand as belonging exclusively to man." This view of the subject has always impressed itself upon the minds of acute observers in all ages. Aristotle said, that man alone possesses hands deserving of the name. Anaxagoras said, that "man is the wisest of animals, because he possesses hands." And the opinion, thus uttered by these philosophers some centuries before the Christian era, is fully echoed at the present time.

45. It would seem, then, that, if mere organization be adhered to, as the basis of classification, it is desirable that some ground of distinction in relation to man be fixed upon, which is more definite than the commonly received one. It is to be remembered, however, that, in classification, some one very obvious peculiarity that presents itself to the eye is ordinarily made use of as a mark of distinction, while accurate and full discriminations are followed out entirely separately from the mere classification. This is done in the case of man. His structure differs in *many* respects from that of the inferior animals. It would make this chapter too long to point out all the differences. Some of them are important, while others are not. As an example of the latter, I will mention the fact, that no animal but man has a *chin*. Every other animal has its lower jaw retreating from the teeth, instead of projecting forward below, as in man. One of the most important and striking peculiarities of man's structure is that general arrangement which enables him to be in the *erect posture*. No other animal naturally assumes this posture, or is able to maintain it for any length of time; and most animals assume one which is entirely the opposite of this. Even the monkey, when taught by man to stand and walk, is by no means erect; but his lower limbs are crooked, and the moment that he escapes the necessity of being an imitator, he is on all fours. There is a distinction of an interesting character, which concerns both the nervous and muscular systems. I refer to the fact, that no animal but man can shed tears, or perform those muscular motions which are necessary to the acts of weeping and laughing. In view of this marked distinction, man has sometimes been designated as "a laughing and crying animal."

46. But the great essential distinctions, to which all the rest are really tributary, are, as I have before stated, of a mental or

spiritual character. And these should always be made peculiarly prominent, whenever the distinctions between man and the inferior animals are treated of by the naturalist. This should be done, not only because they are essential, but also because, as I have just hinted, all other distinctions are subordinate and tributary to them. It is the mental peculiarities of man, for the most part at least, that render necessary those peculiarities which distinguish his organization from that of other animals. I will not dwell on this point, as I shall speak of it in another part of this book.

47. In view of this whole subject, it may be said, that the classification upon which I have commented is not of itself of very great importance, provided that the definite distinctions, which have been pointed out as existing between man and other animals, be clearly recognized by the naturalist. The tendency, however, evidently is, to lose sight of these distinctions in the exclusive regard which is paid to mere material organization. This tendency, it is true, is effectually counteracted in the case of the great majority of scientific men, by the comprehensive and Christian views which they take of the whole subject; but, still, it manifestly exists, and gives rise to many sceptical notions, especially in superficial and theorizing observers. Great care, then, should be taken to oppose this tendency in all public teaching on this subject, whether it be done by books or lectures.

48. There is a disposition, on the part of some writers, to obliterate the grand distinction between man and the inferior animals, and other distinctions which are stamped by the Creator upon his works. Some go so far as to maintain, that there is not only no line to be drawn between the animal and the vegetable kingdoms, but none even between organized and unorganized substances. Robinet, and many other European authors, teach that all matter has living properties, and that every object that we see, whether mineral, vegetable, or animal, is the result of repeated and progressive efforts of nature. The ultimate aim of these efforts is considered to be the formation of man, who is looked upon as the perfection of organization evolved by these efforts. In advocating this theory, they make great use of resemblances and analogies, and even represent the fantastic shapes which minerals sometimes assume, from their slight resemblance to parts of the human body, "as so many proofs," in the language of Carpenter, "of this long and bungling apprenticeship of nature to man-making." Although

such ridiculous doctrines are seldom formally advanced, there is a disposition in many scientific men to indulge in speculations which have more or less resemblance to them. They seem disposed to confuse with the veil of mystic scepticism the clear characters which God has imprinted upon the manifestations of his power. It is well, therefore, to fix these characters definitely in the mind, in order to guard against the fascinating and bewildering speculations of a false science. A true science, forsaking the mazes of speculation, and inquiring only for the facts, reads with admiration and reverence the clear lines of God's handiwork, and attributes to no imaginary agency, termed Nature, what bears the marks of exquisite design and Almighty power.

49. An idea, somewhat akin to that of Robinet, is sometimes entertained, viz., that the varieties in the mineral, vegetable, and animal kingdoms are mere gradations in nature. There would be some plausibility in this notion if it were difficult to distinguish the minerals of the most perfect kind from the lowest plant, and then the plants of the highest order from the lowest animal. But the difficulty lies in other quarters. The most perfect in the three kingdoms are distinguished from each other in the most marked manner; and it is only when the characteristic qualities are the least developed that there is any difficulty. One kingdom is a no more perfect formation than another. The crystal, with its exact lines and angles—the plant, with its curvilinear and less definite shapes—and the symmetrical animal, are equally perfect in their kind. Each is made for a definite purpose, and is perfectly adapted to that purpose. In none is there any imperfection which could be remedied by endowments taken from another kingdom of nature. In the vast variety of forms which nature presents, there is to be seen no vain struggling after a higher and better state. There is no progressiveness, aiming at an ideal perfection. Neither are there gradations leading to it. All the works of the Creator are perfectly adapted to the spheres which they fill. They were all, from "man, made in His image," down to the humblest animal or plant, pronounced to be "very good," as they came from His hand.

50. Let me not be understood to say that there are no gradations in nature. There are some of a very interesting character; but they do not obey any such laws as those which are indicated by Robinet and other fanciful theorizers. There are gradations in both the animal and vegetable world. You ob-

serve them as you go from the simplest plant up to the most complicated. And so of animals. But these two kingdoms of nature are separate in their gradations, and are not in one series together, as is represented by Robinet. And the gradation in each kingdom is by no means an unbroken and regular one, going up, step by step, from the lowest to the highest. For example, in the animal kingdom, there are not constant and regular additions made, as you trace the gradations upward. And though man stands at the top of the series, it is not as a compound, made up of all the excellencies found below him, with additional excellencies peculiar to himself. Superior as he is, as a whole, to all other animals, yet in some respects he is inferior to many of them. He is inferior to them in the wonderful capabilities of instinct. Some animals can do some things better than he can. The monkey is a better climber. Some animals can do what he can not. Birds and winged insects fly, but he can not. These points could be illustrated to any extent, but this will suffice.

51. Man is often spoken of as being the most *perfect* of animals. This, as you will see from what was said in a previous paragraph, is not true in the strict sense of the word. His organization is more complicated, and he has more and higher endowments than any other animal; but the perfection of structure, and of adaptation in contrivance to the purposes aimed at, is as manifest in all the varieties of animals as it is in man.

52. In one respect, there is a gradation existing through the three kingdoms of nature. It is in regard to formation or nutrition. All the elements which are found in the composition of animals exist in the mineral world. But these elements, with very few exceptions, can not be transmitted *directly* to animals, but they are transmitted indirectly through vegetables. No animal, therefore, can live on mineral substances, although these substances contain all the elements found in its composition. But vegetables draw their nutriment from the mineral world, and then furnish nutriment to animals. There is, therefore, in relation to formation, a gradation running through the three kingdoms, from the mineral up to the animal.

53. At the summit of the last step in this gradation stands man. To him, not only is the animal kingdom tributary, but so, also, are the mineral and vegetable kingdoms. They are all made for him, to beautify and gladden this his temporary home,

and to sustain him in it. The subjection of them to him was undoubtedly perfect in his primeval condition of innocence in the garden of Eden. But now, we see this tributary subjection manifested only as a general fact, with many exceptions. These mark this life as the imperfect state, and this world as the temporary home of man, in which he can prepare himself for the perfect and everduring state and home of another life beyond.

PART SECOND.

CONTAINING,

CHAPTER IV.—General Views of Physiology, with a Brief Account of some of the Structures in the Body. CHAPTER V.—Digestion. CHAPTER VI.—Circulation. CHAPTER VII.—Respiration. CHAPTER VIII.—Formation and Repair. CHAPTER IX.—Cell Life.

CHAPTER IV.

GENERAL VIEWS OF PHYSIOLOGY, WITH A BRIEF ACCOUNT OF SOME OF THE STRUCTURES IN THE BODY.

54. The contents of the previous chapters are preliminary to the consideration of the real subject of this work, the Physiology of Man. But they were necessary, in order to accomplish a very prominent object which I have in view. It is my wish that the student, as he examines the functions of the human system, should at the same time observe the analogies existing between man and other living beings, in the processes of life. He will, in this way, get an enlarged view of man in his relations to the world around him, and will be prompted to observe the phenomena of life, in whatever department of nature they may be presented to his view. And, in order to promote this object effectually, I shall, as I proceed with the development of the physiology of man, refer occasionally to the analogous phenomena in other animals, and also in plants. This will serve to fix more definitely in the mind of the student the main facts that are to be communicated, at the same time that the boundaries of his knowledge will be extended over fields full of interest.

55. This is a work on Physiology, and not on Anatomy. Physiology treats of the offices or functions of the different parts of the structure, while Anatomy has regard to the structure itself. In the following pages, I shall introduce the anatomy of the system only so far as it is necessary to elucidate its physiology.

Before proceeding to an examination of the individual subjects which will claim our attention, it will be proper to present some general views of them in their relations as a whole.

56. You have seen, in the preliminary chapters, that organized living beings have much that is common to them all. This is true so far as nutrition is concerned. You have seen that the animal grows very much as the plant does, and that the arrangements for its growth vary from those of the plant only so far as the difference of the source of its nourishment, and of the circumstances under which it is obtained, require. The grand distinction, as you have seen, between animals and vegetables is to be found in the functions belonging to the nervous system. These functions are wholly separate from the *nutritive* functions, which animals perform in common with plants.

57. This view of the subject suggests a natural division of the physiology of man into two parts, viz., the nutritive functions, and the animal functions, or those connected with the nervous system. In other words, the first division will comprise all those subjects which relate to the *building* and *repairing* of the human structure; and the second will comprise those which relate to the *uses* for which the structure is made. The first class of subjects includes digestion, circulation, respiration, formation, and excretion. The second class includes locomotion, sensation, the five senses, the voice, instinct, thought, &c.

58. The student will see at one glance, that a wide range of exceedingly interesting subjects opens before him. Contemplated as a mere mechanism, the human system is full of wonders. The principles of common Mechanics, of Hydraulics, of Pneumatics, of Optics, of Acoustics, are abundantly illustrated in the human body, by contrivances of the most exact and exquisite adaptation. But this congeries of beautiful mechanisms is all regulated by a nervous system, making it, by its minute fibrils, to be alive with feeling in every part. Sensation and sympathy govern, through the nerves, in a wonderful manner, the ever-varying adjustments of all the parts of the complicated system. It is not only mechanism, but living mechanism, that develops to us its wonders, so numerous and diversified. And then, when we look at the soul—"that side of our nature which is in relation with the Infinite"—connected as it is by the nerves with every part of this mechanism, the interest of the study before us appears exceedingly great, and its variety never ending. The study is a peculiar one. It is not the body merely that you are to study in these pages; but it is the body and spirit united. The study differs from all others in this respect. In other studies, you look at either matter alone, or

spirit alone; but here you look at them both, as brought together in mysterious union.

59. It will be proper, here, to say something in general of the structure of the human frame, before proceeding to a particular view of individual subjects. I do this in order to avoid a frequent turning aside for explanation, which would not only be inconvenient, but would mar the interest of the study. It will not be necessary to go into a full description of the numerous and diverse textures, or tissues, (as they are commonly called,) of the body. I will notice only some of the principal of them.

60. From the osseous or bony tissue, the solid part of the framework of the body is made. Bone is composed in part of animal matter, and in part of mineral. The mineral part is mostly phosphate of lime. These two parts of bone are in different proportions to each other in the different periods of life. The mineral part in the child is about one-half of the bone; in the adult, four-fifths; and in the old, seven-eighths. The bones are therefore very brittle in old age, while they are somewhat yielding in childhood. The mineral and the animal portions of bone can be separated from each other. If a bone be put into diluted muriatic acid, the mineral part will after a time become united with the acid, and the animal part will be left, having the perfect shape of the bone. Thus separated from the mineral part, it is so flexible, that it can be tied into a knot without affecting its shape. On the other hand, by subjecting a bone for some time to the action of heat, the animal part can be removed, and the mineral part be left by itself.

61. The animal part of bone is cartilage, or gristle. This part is formed first, constituting a sort of mould, in which the bone is to be formed. The mineral matter is gradually deposited in the cells of the cartilage. In the very young child, you can see that this process is not completed, especially if you observe the bones of the head. The bones are not united together, as they are in the adult; and there is so little of mineral matter near their edges, that they can be bent with a very slight pressure. The proportion of mineral matter which is deposited in the cartilaginous bones varies much in different animals. In many fishes, there is almost none of this deposit, the skeleton retaining its cartilaginous character throughout life.

62. Besides the cartilaginous portion of bones, there are car-

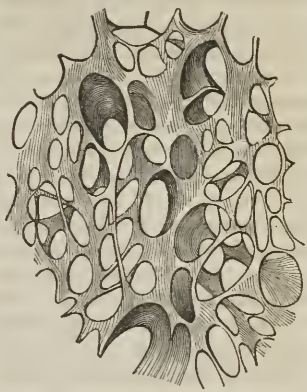
tilages which are destined to remain so, instead of having mineral deposits made in their cells. The ends of the bones are tipped with them. They are placed between all the twenty-four bones of the spinal column. They form the connecting links between the breastbone and the ribs. Cartilage constitutes the body of the outer ear, of the eyelids, and of the lower part of the nose. The transparent part of the eye is formed of cartilage. This substance is placed wherever firmness and tenacity are required without hardness.

63. The bones are united together by ligaments of various degrees of strength, according to the necessity of the case. They are moved by muscles, which, in man, are bundles of reddish fibres. Muscular substance is what is commonly called the *meat* in animals. It is of various colors in different animals, or in the same animal at different periods of life. All motion in animals is produced by muscles. I will not go into an explanation of their action now, any further than to say, that they act by contracting or shortening their fibres. Commonly there are tendons united with the muscles. These tendons are composed of strong white fibres, and have no power of contraction themselves. They serve merely as the cords by which the contracting muscles move the bones and other parts.

64. The most common tissue in the body is what is called by the names, cellular membrane, cellular tissue, and areolar tissue. This last name is most commonly used by physiologists at the present time. The word areolar comes from the Latin word *areola*, meaning a small open space. The term is appropriate, because this tissue is filled with minute spaces or cells. The word cellular is quite as appropriate; and, as this will be more familiar to you, I shall make use of it whenever I shall have occasion to speak of this tissue. That you may understand what this tissue is, I will refer you to its appearance as you see it in different meats. It is the delicate white substance that you see between the different layers of muscle in a piece of meat. If you notice particularly, you will see that it is also between all the different fibres of the muscles. As the spaces or cells communicate together, butchers sometimes "blow up" this tissue in veal, in order to make the meat look more plump. This tissue is the universal packing material of the body. It is to be found almost everywhere. It surrounds every thing,—vessels, nerves, muscles, organs, &c. It enters into their composition, uniting together different tissues, and

also the fibres of the same tissue. It varies much in its compactness in different parts. It is very fine and compact where it is necessary that it should be so; while in other cases it is loose and delicate, allowing a free motion of the parts which it envelops and connects together. It is abundant and loose among the muscles, and between them and the skin. Fig. 2 represents a portion of cellular tissue, inflated and dried, exhibiting the arrangement of its larger meshes. This is magnified twenty diameters. The free communication which exists between the interstices or cells in this tissue is exemplified in dropsy. These cells are bathed, in the healthy state, with a small amount of a watery fluid; and when this increases largely, forming the disease termed dropsy, it obeys the force of gravity in the cells, and accumulates most in the lowest parts of the lower extremities. This tissue is very elastic in health, so that if you press on the skin, there is no indentation left when the pressure is taken away, for the elastic cellular tissue at once rises from its state of compression, pushing the skin before it. But in dropsy it loses its elasticity by over distension; therefore there is pitting, as it is termed, after removing the pressure. We sometimes have an opportunity of seeing the communication between the cells manifested by the introduction of air into them. This has occurred in some cases in which an opening has been made, by disease or accident, from the air tubes in the lungs into the cellular tissue in the walls of the chest. The whole body has been seen largely swollen, from the air which has from this cause accumulated in this tissue directly under the skin. Among the many tricks of impostors, the inflation of the cellular tissue of the head has been practised; and as it produces a frightful appearance, and therefore excites pity, the trick is a very successful one.

FIG. 2.



CELLULAR TISSUE.

65. There are here and there in the cellular tissue deposits of fat. Various purposes are answered by these deposits. They are sometimes of use in promoting a free motion of the adjacent parts. The eye has, intervening between it and the bony socket, a cushion of fat, on which it rests, and against which it is pressed when any violence is offered to it. Fat, as a non-conductor, is a protection against the cold, and it is therefore deposited largely in the cellular tissue under the skin, in animals that inhabit cold climates. Fat, also, sometimes serves as nourishment to the system when its necessities require it. In diseases in which food cannot be taken in any amount, the fat is absorbed into the system. The heat of the body is maintained also, in part, by this process. This occurs in the torpid condition of hybernating animals. They commonly become very fat in autumn, as a preparation for the winter, and in the spring they come forth very lean, their store of fat having been used up for the purposes of nutrition and heat during their confinement. The fat thus deposited in the cellular membrane or tissue is not diffused merely in the interstices, but it is confined in cells of its own, which lie in these interstices. Minute blood-vessels pass from the fibres of the cellular tissue to these fat cells. The fat, which is an oily fluid, is kept from oozing through the pores of the cells that hold it by the blood, which is very nearly four-fifths water, and by the watery fluid which I have spoken of as bathing all the interstices of the cellular tissue; for oil, you know, will not pass through any porous substance that is wet with any watery fluid. If a portion of cellular membrane containing fat be dried, the fat, which in the moist state is wholly confined to its cells, now oozes through their pores. This is the reason that a lump of fat, as it is called, feels so oily after it has been exposed for a while to the air.

66. The mucous tissue is that which lines all the cavities of the body that have outlets. It lines the mouth and the cavities of the nose, and descends into the lungs, the stomach, &c. It takes its name from the fluid called *mucus*, which is constantly secreted by innumerable minute glands, that are situated in the substance of this membrane. The chief object of this viscid fluid is to protect the membrane from the substances which come in contact with it, which would otherwise produce some irritation. This membrane is continuous with the skin, shading off into it insensibly, as you may observe on the lips.

67. The serous tissue or membrane forms the outer coat or

lining of nearly all those organs the inner coat of which is mucous membrane. This is the case with the lungs, the stomach, and the intestines. The serous membranes are white, smooth, and shining, and are lubricated with a watery fluid, called *serum*. Every serous membrane forms a cavity or sac without an outlet, differing in this respect entirely from the mucous membranes. Thus, in the case of the lungs, the serous membrane lining the outside of each of these organs passes from the lungs to the walls of the chest, lining the inside of them, and thus makes a sac without an outlet for each lung. This sac could be dissected off, and taken out whole. When the fluid which lubricates the inside of this sac increases to any extent, the disease called dropsy in the chest is produced. The membrane which thus lines the outside of the lungs and the inside of the walls of the chest is called the pleura, and it is the seat of the disease termed pleurisy.

68. I have thus described some of the principal of the tissues which make up the human structure. The other tissues will be spoken of in the proper connection as we proceed. Before dismissing this subject, I will call your attention to the fact, that the organs of the body are generally composed of several tissues united together. Thus, the stomach has three coats, as they are termed,—the mucous as the inner coat, the serous as the outer, and the muscular between them. And then we have the cellular tissue uniting these together. Besides these, there are arteries, and veins, and nerves, so that the stomach, which looks like a simple pouch, is really quite a composite thing. And the same can be said of the other organs.

69. Before entering upon the particular consideration of the functions by which the system is built up and kept in repair, it will be well to take a general view of them, that you may see them in their connection and mutual dependence. Each of these functions has its special and appropriate part to play, in effecting the formation and repair of the structure. The material from which all parts of the body are formed and repaired is the blood. There are organs whose special duty it is to make this material; organs which distribute it; and organs which use it after it is distributed. There are also organs whose duty it is to receive the blood after it has been used, and fit it to be used again. This common building material of the body is made out of the food; and the succession of processes by which it is done I will describe in the next chapter. After it is made, it is distributed by the complicated apparatus of the

circulation. This apparatus is therefore the common carrier of the building material of the system. It is the numberless little formative vessels, so small as to be invisible to the naked eye, that use the blood thus brought to them, and make and keep in repair all the various structures that we see in the body. When the blood has been used by these formative vessels, it is not fit to be used again until it is submitted to a purifying process by exposure to air; and to this particular object the lungs are devoted. And besides all this, as there are continually some particles which, in the wear and tear of the machinery, become useless, and even injurious, they must be got rid of in some way; and so there are organs for this purpose—organs of waste, as they are termed. It is also to be remembered, that the processes to which I have now alluded are so carried on, that the heat of the body, as will be fully explained hereafter, is steadily maintained. In the following chapters of this part, I proceed to a particular examination of the functions of which I have now given a brief summary.

CHAPTER V.

DIGESTION.

70. I SHALL include, under the term digestion, all those processes which are necessary to effect the separation from the food of its nutritious portion, and the introduction of it into the circulation. A summary of these processes may be thus given. The food is broken up and ground in the mouth, and it is at the same time mixed with the saliva. It is then taken into the stomach, where it is kept in constant motion, and is under the solvent action of a fluid of a peculiar character. When it is brought into the right condition, it is passed from the stomach into the intestines. Here it is acted upon by two fluids, the bile, the secretion of the liver, and the secretion of another gland, the pancreas or sweet-bread. These secretions have some agency in separating from the mass its nutritious portion, and this is taken up or absorbed, in the form of a milky fluid, by little vessels lying on the surface of the inner membrane of the intestine. These vessels unite together to form a large tube, and through this the milky fluid is poured into the circulation, to replenish the blood.

Having given this summary of the processes which make up digestion, I proceed to speak of them more particularly in the order of their succession. In doing so, I shall notice some of the points in which other animals differ from man, in regard to these processes and the arrangements of the apparatus of digestion.

71. Mastication is an important part in the process of digestion. The teeth, which perform this act, are very hard bodies. The body of a tooth is composed of two substances. The inner part is called the ivory, and the outer is called the enamel, which is exceedingly hard. The teeth are of different shapes for different modes of action. There are long and pointed teeth, for tearing; others, for cutting, which have a sharp edge; and others, for grinding, having for this purpose a broad and irregular surface. The teeth are differently shaped in animals, according to the kinds of food which they eat. Thus, the herbivorous, or vegetable-eating animals, have grinding teeth to bruise their food; while the carnivorous, or flesh-eating animals, have sharp-edged teeth and long-pointed teeth, by which their food is torn and cut in pieces. And it is to be observed, that the movement of the jaws always corresponds with the character of the teeth. In the carnivorous animals, the motion of the lower jaw upon the upper is a mere up-and-down, or hinge-like motion. As they have no grinding teeth, there is no need of any lateral or grinding motion. But in the animals that have grinding teeth, there is a lateral motion, to enable them to grind. You see this difference very plainly, if you observe the dog and the horse while they are eating. In Fig. 3, you see represented the teeth of a carnivorous animal. The front teeth are long and pointed, for rending, while the back

FIG. 3.

TEETH OF CARNIVOROUS ANIMAL.

FIG. 4.

TEETH OF HERBIVOROUS ANIMAL.

teeth have a sharp edge for cutting. In Fig 4, you see represented the broad and irregular grinding surfaces of the teeth of herbivorous animals. In animals that live on insects, the teeth present conical points, which press into corresponding depressions in the opposite jaw, as represented in Fig. 5. In those that live on soft fruits, the teeth are rounded, as in Fig. 6. These are quite in contrast with the tearing teeth of the carnivorous, and the grinding teeth of the herbivorous.

FIG 5.

TEETH OF INSECTIVOROUS ANIMAL.

FIG. 6.

TEETH OF FRUGIVOROUS ANIMAL.

72. There is an arrangement of the enamel and the ivory in the teeth of the herbivorous which ought not to pass unnoticed. Instead of having the enamel cover the ivory, as in the teeth of the carnivorous, the two substances are arranged in upright layers, as seen in Fig. 4. The object of this is plain. The ivory wears away faster than the harder enamel, and, therefore, the surface of the tooth always presents projecting hard ridges, fitting them for grinding thoroughly. A miller would say, that these are stones that never need picking.

73. So perfect is the correspondence of the teeth with the kind of food on which the animal lives, that the skillful naturalist can infer very correctly, from the examination of the teeth of an animal alone, the character of the food on which it lives, and even the general arrangement of its structure. As man has the three kinds of teeth which I have noticed, he is said to be *omnivorous*, or an eater of all kinds of food. In him, the front teeth are the cutting ones; what are called the stomach and eye teeth are the tearing ones; and the large back teeth are shaped for grinding. It will be observed that the tearing teeth, as they have not a very sharp point, and are no longer than the other teeth, have but little power when compared with the long and sharp tearing teeth of a carnivorous animal, as seen in Fig. 3. As man can make use of instruments to cut

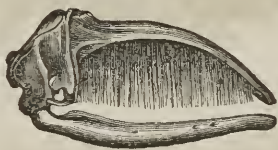
his food in pieces, he does not need such power in his teeth as carnivorous animals have. Allowance should be made for this in estimating the amount of carnivorous adaptation in man.

74. There are a few of the Mammalia that have no teeth. This is the case with the common whale. In his case, instead of teeth, there hang down from the upper jaw, as represented in Fig. 7, plates of a fibrous substance, called whalebone, which have their fibres separated at their free extremities, so as to make a sort of sieve. This is intended to catch the little gelatinous animals, which the whale devours in great numbers.

FIG. 8.

WHALEBONE.

FIG. 7.



SKULL OF WHALE.

For this purpose, he draws in the water, making it to pass through this sieve, and then expels it from the nostrils or blowholes. Birds, too, have no teeth. Their place is supplied by a contrivance in the stomach itself, for the breaking up of the food. This will be described in another part of this chapter.

75. While the food is cut and ground by the teeth, it is at the same time thoroughly moistened by the saliva, which is poured forth from certain glands in the neighborhood. There are three pairs of these glands. Fig. 9 shows the glands on one side. The parotid gland, 1, is the largest. This is situated in front of the lower part of the ear. It is the seat of the swelling in the disease called mumps. Its duct, 2, passes over one large muscle and between the fibres of another, and pours its contents into the mouth opposite the second small grinder of the upper jaw. If you press on this part of the check, you can

FIG. 9.

SALIVARY GLANDS.

feel in the mouth an increased flow of the saliva. The submaxillary gland, 3, is situated inside of the lower jaw at its lower part; and its duct, 4, opens into the mouth at the side of the frænum of the tongue. The sublingual gland, 5, lies under the tongue, and discharges its secretion by a duct at the side of that organ. These saliva factories, as we may term them, are in much more active operation at some times than at others. They are especially active when we are eating; and it is commonly estimated that, during an ordinary meal, about eight ounces of saliva are poured into the mouth. This large amount is wanted to moisten the food thoroughly before it is swallowed; and it is supposed, also, that it has some chemical influence in preparing the food for the action of the gastric juice in the stomach. More saliva than usual is needed, also, when we are speaking, in order to keep the parts properly lubricated, for the passage of the air in and out during speaking dries up the saliva by evaporation. And, accordingly, the motion of the parts at such times stimulates a larger flow, just as pressure on the cheek will do it, as before remarked. This result is favored by the arrangement of the duct of the parotid gland, which, as you have seen, passes over one large muscle, and then through the body of another. Chewing any thing excites

an increased flow of the saliva; and the tobacco chewer does a real injury to the salivary glands, by keeping them constantly in excessive operation, in addition to the ruinous effects of this drug on the system at large. When he eats, these over-worked factories can not turn out as good an article as they should, nor will it be in sufficient quantity.

76. It is supposed that, besides the mere mechanical stimulus of the motion of the parts, the stimulus of sympathy is also concerned in exciting these glands to increased action. The glands are supposed to be affected in this way by the stimulation of the food on the surface of the mouth, about the orifices of their ducts. That sympathy does have an influence on their secretion is evident from the very familiar fact, that the thought of food will often, as it is expressed, cause the mouth to water.

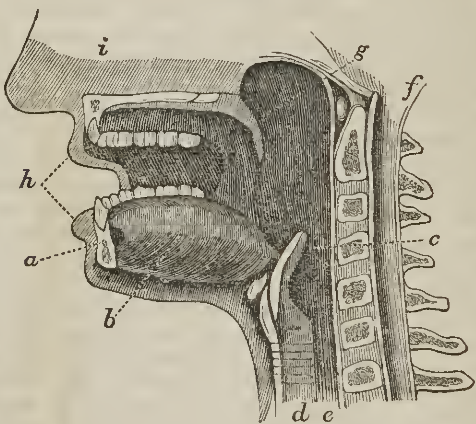
77. The fact, that these glands do not all secrete the same kind of fluid, has led to an interesting discovery in relation to them. The submaxillary glands secrete rather a viscid fluid, while that which is poured forth by the parotid and sublingual glands is perfectly limpid. Now, it has been found, by various observations and experiments on animals, that while the teeth are cutting and grinding the food, and the parotid and sublingual glands are pouring out the saliva to moisten it, no secretion comes from the submaxillary glands. But these glands pour out their viscid fluid the moment that the tongue thrusts the food back towards the throat, in the beginning of the act of swallowing. The special object of this viscid fluid is then to cover the food, so that it may, to use a common expression, slip down easily into the stomach; and it has nothing to do with the moistening of the food, this being the particular office of the other two pairs of glands.

78. When the food has been ground by the teeth, and moistened by the saliva, it is carried by the act of swallowing into the stomach. This act, simple as it appears to you, is a very complicated one, and is performed by the conjoined and agreeing action of many different muscles. The food is first thrust back over the surface of the tongue into the large cavity in the back of the throat, called the pharynx. In the pharynx are the openings of two tubes—the œsophagus or gullet, which is the passage into the stomach, and the trachea * or windpipe, the passage to the lungs. As the œsophagus lies behind the

* This term is sometimes used, as here, to mean the whole of the tube conducting to the lungs, including the larynx, which is at the top of this tube, and sometimes it is restricted to that part of the tube which is below the larynx.

trachea, the food, in passing to it, must go directly over the opening into the trachea. To prevent the food from entering the trachea, therefore, there is a little tongue-shaped body, called the epiglottis, extending back from the root of the tongue, and acting as a lid to the glottis, the opening into the trachea. When we are swallowing, this lid is shut down; but it is always raised up when we are breathing or speaking. When we swallow, not only does the lid shut down, but the larynx rises to meet the lid, as you may readily perceive, if you place your fingers upon what is called Adam's apple while you are swallowing. With the aid of Figures 10 and 11, all this will be very clear to you. In Fig. 10, you have a *side* view of the parts engaged in swallowing, as if the head were divided into two halves by a vertical section. At *i*, is the cavity of the nostril; at *h*, are the lips; *a* is the divided bone of the chin; *b* is the tongue, between which and the spinal column, *f*, is the large cavity of the pharynx. In front of this cavity hangs the

FIG. 10.

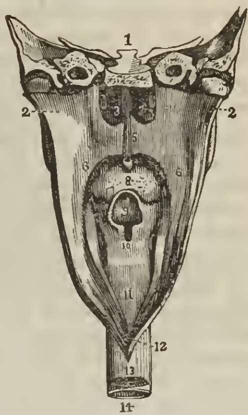


VERTICAL SECTION OF THE THROAT.

palate, *g*, as a door or valve, to direct the air coming from the trachea, *d*, either through the mouth or through the nostrils, according to its position. The œsophagus, *e*, is behind the trachea, and the epiglottis, *c*, shuts down when we swallow, to let

the food pass over it into the œsophagus. In Fig. 11, you have a view of the same parts from the rear. At 1, is a section of the bones at the base of the skull; 3, 3, are the cavities of the nostrils; 2, 2, the walls of the pharynx spread apart; 5, the pendulous palate; 6, 6, the arch of the palate; 8, the root of the tongue; 9, the epiglottis, and 10, the glottis, or opening into the larynx; 13, the œsophagus; 14, the trachea. The pharynx, you see, is a funnel-shaped cavity, tapering down to the œsophagus, the opening of which is considerably below the opening of the trachea.

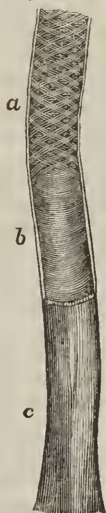
FIG. 11.



VIEW OF THE THROAT FROM BEHIND.

79. When the food enters the œsophagus, it is carried through that tube into the stomach by the action of muscular fibres. These fibres are represented in Fig. 12. The circular fibres are seen at *a* and *b*. These are removed at *c*, so as to show the longitudinal fibres. It is by the consent of action between these different sets of fibres that the food is propelled through the œsophagus. As the food descends, a dilatation of the circular fibres must everywhere take place where the food is, and a contraction of them immediately behind it—the dilatation making the way for it, and the contraction forcing it along. And in animals that chew the cud, these actions must be reversed when the ball of food is forced up through the œsophagus into the mouth.

FIG. 12.



ŒSOPHAGUS LAID OPEN.

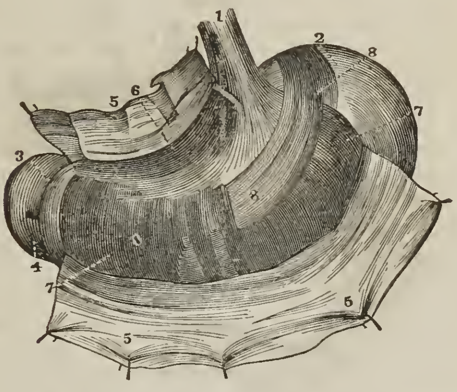
80. The food being introduced into the stomach, is here subjected to the action of the gastric juice. This is a

peculiar fluid, somewhat acid in its character, which is secreted by very minute follicles, or bag-like cavities, situated in the substance of the mucous membrane. Ordinarily there is none of this fluid in the stomach when there is no food there. Dr. Beaumont made some very interesting observations on this, as well as many other points, in the remarkable case which fell under his care. The individual, Alexis St. Martin, received a wound in his left side by the bursting of a gun. The wound, which opened into the stomach, never entirely closed, but an orifice remained, after the healing process had done all that it could. Through this orifice, Dr. Beaumont could look into the stomach, and observe what was going on there. He describes the mucous membrane, in its healthy state, as having a velvet-like appearance, with a pale pink color, and as being covered with a very thin, transparent, viscid mucus. On introducing some food, or irritating the mucous membrane mechanically, he saw, by the aid of a magnifying glass, "innumerable lucid points" projecting on the surface, and from these there exuded a pure, limpid, colorless fluid. These points were the follicles which secrete the gastric juice, now rendered turgescent by being stimulated to action.

81. The amount of gastric juice secreted is generally about in proportion to the amount of food which the necessities of the system require. When the quantity of food taken is very much more than is required, there can not be a sufficient amount of gastric juice secreted to digest all of the food; and some of the food must therefore remain undigested, and will prove a source of irritation to the stomach. If the amount of food taken from day to day is not very excessive, but is only a little above the proper quantity, there will be enough of the gastric juice made to digest it; but the daily overtaxing of the powers of the secreting follicles will, after a while, produce derangement in the stomach, and perhaps permanent disease.

82. The action of the gastric juice upon the food is of a chemical nature. In order that it may act effectually on all portions of the contents of the stomach, this organ is kept in constant motion by the fibres of its muscular coat. These fibres are so arranged that, as they contract and relax, they keep up a sort of churning of the contents, and thus effect a thorough mixture of them with the gastric juice. In Fig. 13, you see these fibres represented. At 1, is the opening of the œsophagus into the stomach; and at 4, is the part which opens into the intestine. The fibres are in different layers, running in

FIG. 13.

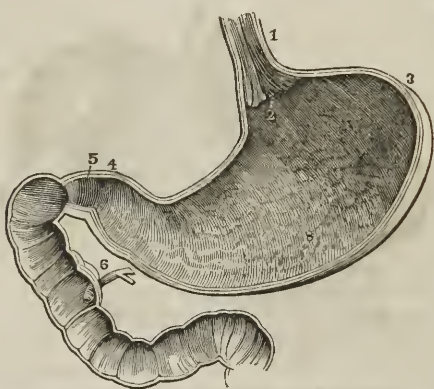


MUSCULAR FIBRES OF THE STOMACH.

different directions. The outer peritoneal coat, 5, 5, is dissected off and turned back, showing some of the fibres that run lengthwise of the organ, 6 ; and some of them transverse, 7 ; and others, 8, that run obliquely. You can readily see what effect the contraction of these different fibres will have on the shape of the stomach. The contraction of the longitudinal fibres, 6, brings the large, bulging end of the stomach, 2, and the small end, 3, nearer together. The transverse fibres, when they contract, diminish the capacity of the stomach transversely. And the oblique fibres modify these two motions by their oblique action.

83. By the combined chemical and mechanical action of the stomach, its contents are, after a little time—in three or four hours—reduced to an uniform, greyish, semi-fluid mass, called *chyme.* While this process has been going on, the communication between the stomach and the intestines has been entirely closed by a valve, called the pylorus. This is represented at 5, in Fig. 14, which presents a view of the inside of the stomach. This valve is made of a fold of both the mucous and muscular coats of the stomach. It is a very faithful sentinel, as is indicated by its name, which is derived from two Greek words, signifying to guard the gate. It will not ordinarily permit any undigested food to pass it. While the process of digestion is

FIG. 14.



INTERIOR OF THE STOMACH AND SMALL INTESTINE.

going on, the motions produced by the muscular fibres cause the contents to move about, and of course they are thrown against the pylorus, as well as any other part of the stomach. But the valve remains closed, until some portion comes against it that is thoroughly changed to chyme, and is therefore fit to pass on into the intestine. It then opens to let this pass, and it does so for any other portions that have become chyme. Toward the conclusion of the digestion of a meal, small quantities pass at first, and after a while, the contents pass quite rapidly through the valve.

84. Although this sentinel-valve thus performs its duty so faithfully in relation to nutritive substances, it seems to let other substances pass very readily. Solid substances, swallowed by mistake, as buttons, pieces of money, the pits and skins of various fruits, often pass the valve without any trouble. The valve seems to be on duty as a sentinel only during the process of digestion; and, if the attempt to go through with this process prove unavailing, the pylorus, though it let such hard substances as I have mentioned pass without difficulty, resists the passage of the undigested food, sometimes causing much uneasiness, and even perhaps pain, by so doing. In such a case, either the valve after a time gives over its resistance, or, hold-

ing out, the action of the stomach is reversed, and the offending matter is thrown off by vomiting.

85. It is not a little amusing to read the different theories which were formerly broached to explain the process of digestion. Some supposed it to be a *concoction*, heat being, in their view, the chief agent; some, a kind of *putrefaction;* some, a *chemical solution;* some, a *trituration;* and some, a process dependent upon the action of the nerves. Of these various theories, the celebrated Hunter playfully remarked: "To account for digestion, some have made the stomach a mill; some would have it to be a stewing-pot, and some, a brewing-trough; yet, all the while, one would have thought that it must have been very evident that the stomach was neither a mill, nor a stewing-pot, nor a brewing-trough, nor any thing but a *stomach.*" All these theories are now done with; and it is pretty well ascertained, that digestion is a chemical process—in part a solution, and in part a fermentation—and that mechanical agency is employed only for the purpose of thoroughly exposing the food to the action of the gastric juice.

86. The process of digestion, as it has been described, is a regular process, requiring a certain average period of time for its completion. If, during the progress of it, fresh food be introduced, its regularity is broken in upon, and the process fails to be well done. Then, too, if, immediately after the completion of the process, a new supply of food be taken, harm is done, because the organ has not its needed interval of rest. For these reasons, the practice of eating between meals is a very injurious one. Eating fast does harm, because,—1st, the food is not sufficiently ground; 2d, it is not mixed thoroughly with the saliva; and, 3d, more food is taken than would be sufficient to satisfy the hunger if the individual ate slowly, and, therefore, more than can be easily digested. Great variety in food stimulates the appetite unduly, and too much is consequently eaten. Exercise facilitates digestion, if it be not violent. An experiment was once tried upon two dogs, which was thought to prove that exercise hindered digestion. Two dogs were fed freely, and while one was left to lie still, the other was made to run about violently. Both dogs were killed after an hour or two, and it was found that, while digestion had gone on thoroughly in the dog that was allowed to remain quiet, in the other the food was undigested. This only proved that *violent* exercise, taken immediately after eating, impedes digestion. It has been found, on the other hand, that light exercise pro-

5*

motes the process; and daily experience, among laborers, shows, that very strong exercise does not interfere with it, if a little interval of rest be allowed, so that the process may be fairly begun.

87. The sensation of hunger has been attributed to various causes,—as the empty state of the stomach, the presence of the gastric juice irritating the mucous membrane, &c. It cannot arise from emptiness; for, if it were so, it should occur sooner than it does after eating, and it should not be absent in disease, as it often is for a long time, when the stomach is almost entirely empty. It can not arise from the irritation of the gastric juice; for it was found by Dr. Beaumont, in his observations of the stomach of Alexis St. Martin, that this fluid is not secreted till after food is introduced into the stomach. The cause of hunger is evidently in the state of the system. It is a state of want. Nutriment is needed by the formative vessels, the builders and repairers of the system, of which I shall speak particularly in the chapter on Formation and Repair. And they make their wants known as distinctly as the bricklayer does, when he calls for more brick and mortar. Through the nerves, an impression is communicated from these to the stomach, and the sensation of hunger is the result. That the sensation is seated there is evident from the fact, that it can be temporarily relieved by putting indigestible substances into the stomach. These produce the effect by causing other sensations there, which take the place, for the time being, of the sensation of hunger. After, however, the momentary effect is over, the sensation of hunger returns again in its full force. The *cause*, then, of the sensation is in the system at large, but its *seat* is in the stomach. Its degree of urgency depends upon this general state that causes it. If eating be delayed much beyond its usual time, or if the system has been exhausted by the wear and tear of severe labor, the sensation of hunger is very urgent. So, too, if disease has impoverished the system, as soon as the stomach is in a condition to respond to the call of the formative vessels that set themselves to work to repair the waste, the hunger is often excessive. Observe, here, that in order to have the sensation of hunger, not only must there be a want in the system at large, but the stomach must be in a state fitted to receive the notice of this want. And fortunately it is seldom in this state except when in a condition to do its work. If it were otherwise, food would often be introduced into it when it could not be digested. The stomach is sometimes incapacitated

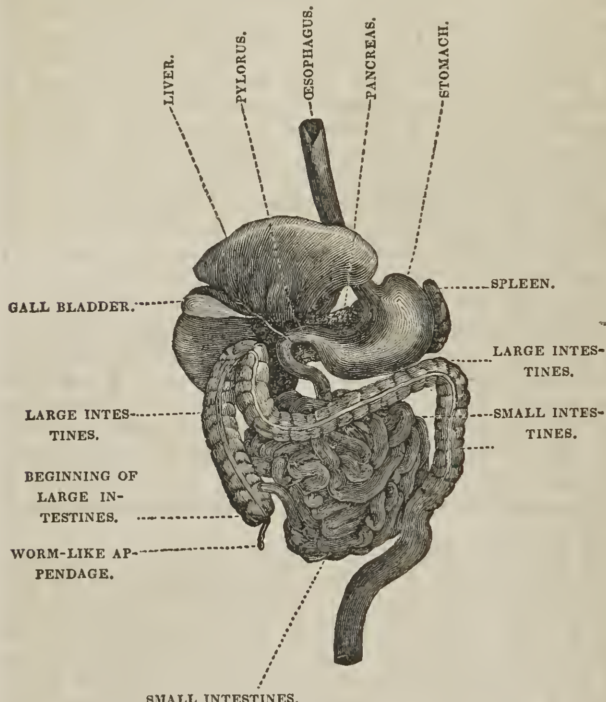
for receiving the notice of the want of the system by mental impressions. In this case, an impression is communicated from the brain to the stomach, through the nerves, which counteracts the impression conveyed from the system to this organ, and so neutralizes the sensation of hunger. Grief thus often destroys the appetite for food. One thing more is to be observed in relation to hunger. Although this sensation is caused by the want of the system, it is removed long before the nutriment reaches its final destination, and supplies the want. How is this? It is either because the new sensations produced in the stomach, by the commencing process of digestion, take the place of the sensation of hunger, or an impression is sent all over the system from the filled stomach, which, so to speak, stills the clamor of want with the immediate prospect of a supply.

88. Nearly the same remarks can be made in relation to thirst, that have been made in regard to hunger. The seat of this sensation is in the fauces or throat. Its cause is evidently not there; for the mouth and throat may be very dry, and yet there may be little or no thirst; while, on the other hand, there may be much thirst, although the mouth and throat are moist. The cause of the sensation is like the cause of hunger, in the system at large; and, therefore, no local cause, producing a dryness of the throat, can cause thirst independent of a general condition.

89. Before describing the remainder of the process of digestion, I will call your attention to the arrangement of the stomach, and the other organs of the abdomen engaged in this process. Fig. 15 exhibits them as they present themselves in a front view, except that they are somewhat separated from each other, instead of being as closely packed, as they are in the abdomen. The large end of the stomach, you see, lies to the left side,* and at this end is the spleen. The pancreas is behind the right end of the stomach. Above the stomach, and mostly to the right side, is the largest organ in the abdomen, the liver. It is represented as turned upward in the Figure. The stomach is directly connected with the small intestines at the pylorus. At the end of this long and winding tract begin the large intestines. The duct of the gall bladder, and that of the pancreas, empty their contents into the small intestine at its beginning. The office of the spleen has not yet been ascertained. Neither has that of the worm-like appendage at the

* As this is a *front* view, the right side of the Figure is the left side of the body.

FIG. 15.



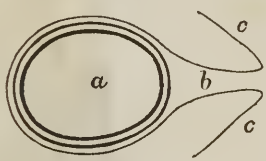
DIGESTIVE ORGANS.

beginning of the large intestines. The omentum, or caul, which hangs like a curtain from the front part of the stomach down in front of the intestines, is not represented in the Figure.

90. There is one arrangement in the abdomen which must not pass unnoticed. If the intestines were left to lie loose in this cavity, they would constantly be subject to displacement and injury. They are therefore fastened to the backbone by an arrangement, which secures them from any such accident, and at the same time allows of a sufficiently free motion of differ-

ent parts of this tube. It is this. The intestinal tube makes the margin of a broad sheet of membrane, the other edge of which is gathered up and fastened to the spinal column. The arrangement is like a ruffle with a puffed edging. The membranous sheet is called the mesentery. As the intestinal tube, the puffed edging, is much longer than the ruffle itself, the mesentery, it is gathered on to the ruffle, as a seamstress would express it. Now, the mesentery is composed of two folds of the peritoneum, the smooth, shining, outer covering of the intestines. The arrangement will be easily understood by the diagram in Fig. 16, which represents a section of the intestine with the mesentery. The cavity of the intestine, *a*, is lined by the mucous membrane represented by the inner circle. Next comes the muscular coat, and next the peritoneal, the outer, which, instead of making a circular tube, as the other two coats do, passes backward on both sides of the intestine, to make the mesentery, *b*. After being attached to the spine by means of cellular tissue, it is reflected off to pass over other portions of the intestine, as seen at *c*, *c*. Between the two layers of the peritoneal membrane, in the mesentery, is considerable space, as seen at *b*. This space is filled up with blood-vessels, nerves, lacteals with their small glands, soon to be described, all bound together by the common packing material of the body, the cellular tissue. You see, therefore, that the mesentery subserves more than one use. Besides fastening the whole tract of the intestinal canal to the spine, so as to guard it against accident, it acts as a secure medium for the communication of the blood-vessels and nerves with the intestines. And, besides, as you will soon see, it contains the little tubes which convey all the nutriment into the blood for the growth and repair of the body.

FIG. 16.

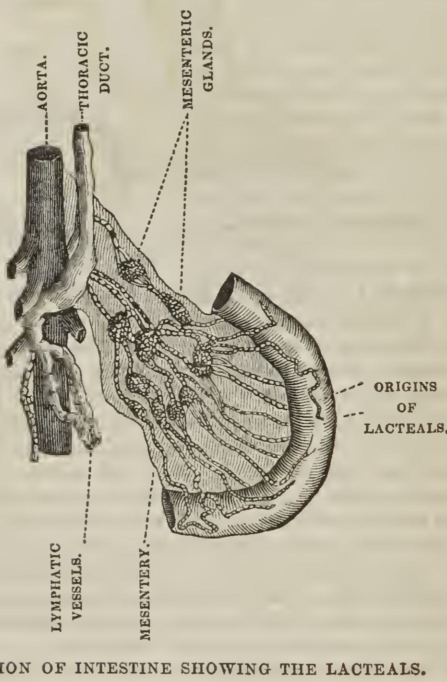


PLAN OF THE MESENTERY.

91. I now go on to describe the remainder of the process of digestion. The chyme, (§ 83,) as it passes into the small intestine from the stomach, has mingled with it the bile and the secretion of the pancreas. These are poured into the intestine at the point represented at 6, in Fig. 14. These secretions undoubtedly have some agency in separating the nutritious part

of the chyme from that which is not so. When thus separated, it is absorbed by the innumerable small vessels, called lacteals, which are situated in the mucous membrane. This nutritious part of the chyme is a milky fluid, called the *chyle*. The lacteals which absorb it are little tubes or ducts. These enter certain glands, called the mesenteric glands, for the purpose of having some effect, we know not what, produced upon it. They then pass on, as seen in Fig. 17, to pour their contents into the

FIG. 17.

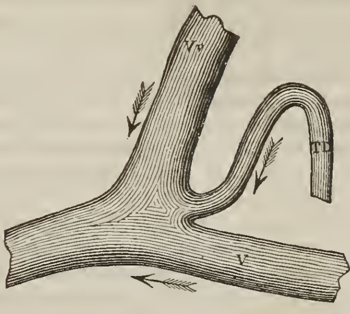


SECTION OF INTESTINE SHOWING THE LACTEALS.

thoracic duct. This duct, which is about the size of a common quill, running up on the left side of the aorta, the great artery of the heart, pours its contents into the junction of two veins at the top of the chest. As the circulation of the chyle in the

thoracic duct needs all the mechanical help that it can have, the mode of the joining of this duct with these veins is calculated to facilitate the freeness of the discharge of the chyle. As the two large currents in the veins, V and V, *v*, in Fig. 18,

FIG. 18.



JUNCTION OF THE THORACIC DUCT WITH THE VEINS.

unite, there is created, by the forward motion of these currents, a tendency to a vacuum at the angle at which they meet, the point where the thoracic duct, T, D, opens. There is, therefore, a suction power, as it is termed, exerted upon the fluid in this duct. The chyle, thus mingled with the blood, becomes a part of it. Or rather, I should say, that the blood is made from the chyle, and, as it is constantly used for formation and repair in all parts of the system, it is thus as constantly replenished. The material by which all the textures of the body are made and are kept in repair, is furnished to the system through this small duct, in the form of a milky fluid. You observe in Fig. 17, certain lymphatic vessels. These are trunks of absorbents, hereafter to be spoken of particularly, which bring a fluid called *lymph*, to be mingled with the chyle, and to be poured with it into the circulation.

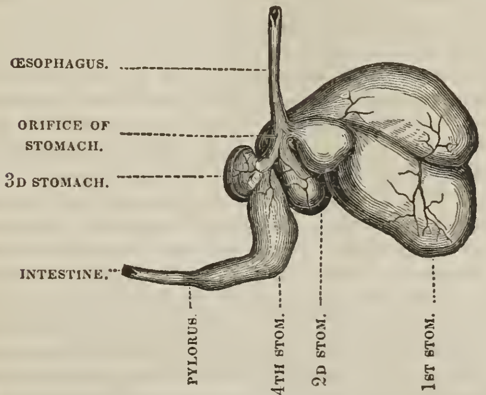
92. The extent of surface on which the absorbent lacteals open can not be appreciated, if you look merely at the outside of the small intestines. It can be done only by looking at the inner mucous coat. This coat is really much more extensive than the outer coat, or the middle one, the muscular, and it is full of folds, as represented in Fig. 14, on page 52. The ob-

ject of this is to offer a very large absorbing surface to the chyme as it passes, and also to prevent its passing along as rapidly as it would if the mucous surface were perfectly smooth, instead of having folds. Before leaving this subject, I would again call your attention to the analogy which exists between absorption in animals and in plants. The lacteals do for the animal in its stomach, what the absorbents do for the plant in the extremities of its roots. Both absorb and assimilate nutriment. The function is the same. It differs in the two cases only in the circumstances under which it is performed.

93. The digestive apparatus varies much in different animals, according to the kinds of food on which they live. As a general rule, the more the food differs in character from the animal itself, the more complicated and extensive is the apparatus. Thus, the herbivorous animals have a very long alimentary canal, and the beginning of it, the stomach, is a complicated organ. While, on the other hand, in the carnivorous, the flesh which they eat being very much like their own flesh, and, therefore, not requiring very much of a process of assimilation, the stomach is a simple organ, and the alimentary canal is very short. In the sheep, for example, the alimentary canal is about twenty-eight times the length of the body, but in the lion it is only three times its length. In man, who lives on a mixed diet, the alimentary canal is about six times the length of the body.

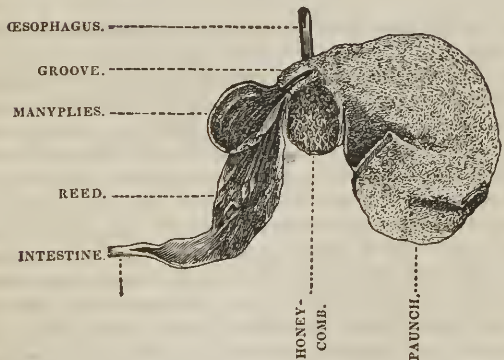
94. The stomach is more complicated in animals that chew the cud than in any other animals. It has four distinct cavities, and, as you will see, a singular mechanism is called into operation in managing the food as it passes through them. In Fig. 19, you have a representation of the stomachs of the sheep, as they appear exteriorly. The course which the food pursues is this. As the animal crops the food, it passes into the first stomach, which is little else than a great reservoir to hold it and to soak it. Then it passes into the second stomach, from which it is returned into the mouth. On being swallowed again, it passes from the œsophagus into the third, and thence into the fourth stomach. In Fig. 20, you see the interior of these four stomachs; and by the aid of this I will describe the process of digestion in the sheep more particularly. You see the very large first stomach, or *paunch*, in which the food is accumulated. It is not yet masticated thoroughly, for the animal has swallowed it as fast as he could, and packed it away in this reservoir. From this it is passed, in small quantities at a time,

FIG. 19.



STOMACHS OF THE SHEEP.

FIG. 20.



INTERIOR OF THE STOMACHS OF THE SHEEP.

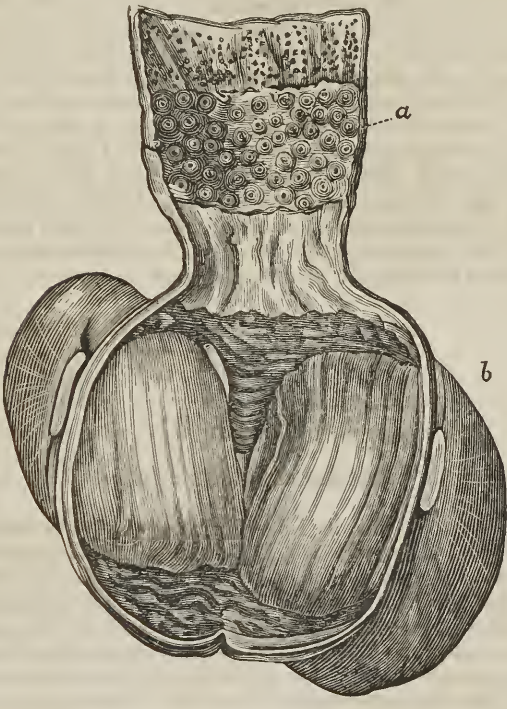
into the second stomach, the *honey-comb*, so called from the peculiar network of folds in it. Here the food is rolled up into balls by the action of the muscular fibres in this network.

Each ball of food is passed up through the œsophagus into the mouth, where it is chewed and thoroughly mixed with the saliva, in doing which the animal seems to have great enjoyment. Then it is swallowed, and, as it passes from the œsophagus, instead of going into the paunch, as it did when swallowed the first time, it is directed through the groove seen in the Figure into the third stomach, the *manyplies*. This has many folds, like the leaves of a book, so that the food is exposed to a large surface in this cavity. It passes from this to the fourth stomach, the *reed*. Here, and here only, it is acted upon by the gastric juice. This, therefore, is the true stomach, all the other cavities furnishing only preparatory steps to the true process of digestion. It is from this fourth stomach that what is called the *rennet* is taken. When fluid matter is swallowed, it goes directly into the second stomach, and not into the first, the paunch; so that, in the case of the sheep, the drink goes one way, and the solid food another. And, what is still more singular, while the animal is a suckling, the milk passes directly into the fourth stomach through the third, which has its folds so closed together as to form a mere tube to conduct it to its destination. And the great paunch and the honey-comb are wholly useless until the animal begins to crop its food for itself.

95. In birds, the digestive apparatus is necessarily very peculiar, from the fact that they do not masticate their food. They have, on this account, an arrangement in the stomach itself for grinding the food. In the cavity called the gizzard are two opposing surfaces, made very hard, so that by rubbing together they bruise the grains; and while they are thus ground, as between two millstones, the gastric juice is poured down upon them from above. This arrangement is seen in Fig. 21, which represents the digestive apparatus in the turkey laid open. At *b* is the gizzard, showing the two hard surfaces, which are rubbed together by the stout muscles that make the great bulk of the organ. Above, at *a*, are the glands which pour forth the gastric juice. And above this part of the stomach there is, in all grain-eating birds, a large sac bulging out from the œsophagus, called the crop, which is a reservoir for the food, just as the paunch is in the ruminating animals. In those birds that live on flesh or fish there is no such grinding apparatus; and the walls of the stomach are quite thin, and it presents no hard surfaces.

96. It would be interesting, were it consistent with the plan

FIG. 21.



STOMACH OF THE TURKEY.

of this book, to go into a further examination of the varieties in the digestive apparatus in different animals. They have a very wide range, being according to the wants of the animal in each case. The kind of food, the mode of life, and the purpose which the animal is designed to fulfill, are the circumstances which govern these variations. The proportion which the digestive apparatus bears to other parts varies very much; and in some of the lower orders of animals, the body seems to be all stomach. In such cases, the only appendages are those which seize the food and direct it into the orifice of this organ. This

is the case with the hydra, represented in Fig. 1. And, what is very singular, the outside of the body of this animal is just as capable of acting as a stomach as its inside. For you may turn it inside out, as you can a stocking, and yet it will go on to catch and digest its food as usual. But, wide as the variations are in the digestive apparatus of animals, the same common object is aimed at in all—the assimilation (§ 10) of nutrient substances to the animal, to produce a material from which its structure can be built and kept in repair. There is, therefore, much that is common to them all in the modes in which this object is accomplished. And even the analogy which exists between the animal and plant, in regard to assimilation, does not relate to the fact alone, but in some measure to the modes in which the process is effected.

CHAPTER VI.

CIRCULATION OF THE BLOOD.

97. In the last chapter I described the manner in which the blood is made from the food. The blood, thus prepared, is circulated in every part of the body, that it may be used for the purposes of construction and repair. The apparatus by which this is done acts, as I have before said, as the common carrier of the material which is used everywhere in the body by the laborers, the builders, to whom it is thus brought.

98. This apparatus consists of several parts—a great central organ, the heart, situated in the chest; the arteries, the tubes by which the blood is conducted to all parts of the body; the veins, other tubes, which bring the blood back to the heart; and capillaries, a network of exceedingly minute vessels, through which the blood passes as it goes from the extreme arteries into the beginnings of the veins. The blood goes from the heart through a large artery, called the aorta, which sends forth branches; and these divide and subdivide, so that the extreme arteries, through which the blood flows into the capillary network, are very minute. And the veins which receive the blood from this network to carry it back to the heart, are equally minute; but joining together more and more, as they proceed

toward the heart, they are at length all united into two great venous trunks, one from above and the other from below, which pour their contents into this organ. The capillaries, taking their name from the Latin word, *capilla*, a hair, are so small that they can not be seen by the naked eye. In any small cut, the blood which oozes out comes from multitudes of these vessels. They serve to hold the blood, while the formative vessels, that construct and repair the body, may select from it such materials as they need for their purposes.

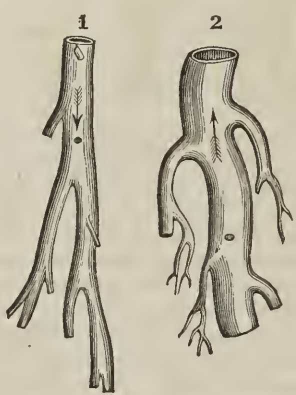
99. The heart is a great central forcing and suction pump, in the midst of this circulating apparatus. When it contracts, it forces the blood out through the aorta and its branching arteries into all parts of the system. And when it enlarges or dilates itself, it, by suction, as it is termed, receives the blood returning from the system through the veins. The blood never ceases to go these rounds. The necessity for this continual motion you will perceive as I proceed with the development of the subject.

100. The arteries differ from the veins in their structure and arrangement. The arteries are firm tubes, while the veins are lax in their structure. The object of the difference is obvious. As the blood is forced into the arteries by the powerful action of the heart, it is necessary that they should be strong and firm, else, they would be liable to dilatation and rupture, and death would frequently result. As it is, it is not a common event to have an artery dilate and burst, though it does occasionally happen. When dilatation does occur in an artery, it is called an *aneurism*. But the arteries need to be firm, not only for the sake of security against rupture, but also that the force of the heart may propel the blood to the extremities of the arterial system. If the arteries were lax tubes, like the veins, the impulse would soon be lost in the yielding tubes, and the blood would move very sluggishly in the small arteries at a distance from the heart. What we call the pulse, is caused by this impulse. If the arteries were lax tubes, the pulse would not be felt at any great distance from the heart. Instead of being distinct, as it now is, with every beat of the heart almost to the very extremities of the arterial system, it would be rendered confused by the yielding of the tubes, even quite near the heart, and at a distance from that organ it would be entirely lost.

101. Besides the firmness of the arteries, there is another circumstance which favors the freeness of the flow of blood

through them. It is their mode of division. The branch of an artery leaves the main trunk at a sharp angle, making thus only a slight deviation from the direction of the current; while, on the other hand, in the veins where the current flows in an opposite direction, the branch unites with the trunk at nearly a right angle. This difference is represented in Fig. 22; 1 being the artery, and 2 the vein.

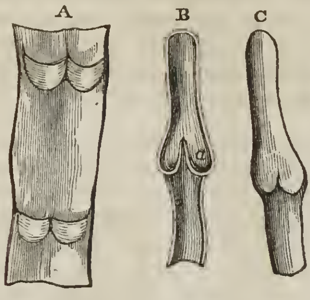
FIG. 22.



ARTERY AND VEIN.

102. The venous system has a much greater capacity than the arterial. That is, all the veins of the body are together capable of holding more blood than all the arteries are. And the blood moves very rapidly and directly from the heart through the arteries, but it comes back to the heart quite slowly through the veins. Every thing is arranged to promote this rapid circulation through the arteries, while the venous system is calculated for a slow but sure progress of the blood back to the heart. To secure this, valves, made of folds of the inner lining of the veins are so arranged as to prevent the blood from flowing in the wrong direction. Fig. 23 represents a vein cut open so as to show these valves. A shows the valves as they appear when the vein is laid open and spread out; B, as they appear when the vein is simply laid open; and C represents the appearance of the outside of the vein where there are valves.

FIG. 23.



VALVES IN THE VEINS.

The need which there is of this help to the circulation through the veins is obvious. The suction power of the heart is not competent, unaided, to move the blood throughout all the lax venous system. These pocket-like valves, therefore, are made in the veins to assist the circulation there. They do so in this way. Every motion of the muscles or other parts about the veins tends to keep the blood in motion, and the valves serve to prevent this motion from being in the wrong direction. The difference in force and velocity with which the blood moves in the arteries and in the veins, is made manifest when they are wounded. The blood flows from a wounded vein in a slow and steady stream. From an artery it flows rapidly, showing the impulse of the heart in its jets, which correspond exactly with the pulse. Hence comes the danger in wounding an artery, while the wound of a vein is ordinarily attended with no danger. Accordingly, we find that the "Maker of our bodies" has so placed the arteries that they cannot easily be wounded, while many of the veins are quite freely exposed. The arteries are deeply seated, except in some few cases where this is impossible; but the veins are often superficially situated. You can see this, for example, in the bend of the arm. Some large veins appear there just under the skin, while the artery which supplies the arm is imbedded among the muscles and tendons. In every part of the body, the most secure spot is chosen for an artery. Thus, at the knee joint, the artery, instead of running over the surface of bone, where it would be liable to be

wounded, lies deep in the ham at the rear of the joint. The same is true of the elbow joint, just alluded to, and of other parts of the body. Although there are arteries everywhere, they are so uniformly deeply seated, that it is only in a few localities that you can readily find one. You can feel one pulsating at the wrist, and also on the temple. Here the arteries are superficial, only because it is impossible that it should be otherwise.

103. When the physician bleeds a patient, he commonly does it at the bend of the arm, as being the most convenient place for the operation. A ligature of some sort, as a ribbon, is tied around the arm above the elbow, with sufficient tightness to interrupt the flow of blood toward the heart in the superficial veins, but not so tightly as to prevent the free supply of blood to the arm by the artery. It is commonly tied as tightly as it can be without stopping the pulse at the wrist. An opening is then made in one of the veins; and, as the blood flows freely into the arm from the heart through the artery, on its return, so much of it as passes through the opened vein is discharged at that point.

104. It will be proper here to give some practical instruction, in regard to stopping the flow of blood from a wounded artery, as many lives have been lost from the ignorance of bystanders when such accidents have happened. Enveloping the part in cloths, which is so commonly done at such times, does no good, but only serves to catch and conceal the blood as it flows. Pressure upon the artery, on that side of the wound which is *toward the heart*, will of course interrupt the supply of blood from this organ to the wound. Firm pressure with the thumb will do it. But the pressure must be made at the right point, that is, directly upon the artery. You may not, in all cases, press upon the right spot at once. If you do not, the blood will continue to flow. In this case, press at different points, until you find the point at which you see that pressure stops the flow of blood from the wound. But you may not be able to find the right spot. If you can not, you can tie a slip of strong cloth or a handkerchief around the limb, *above* the wound, and twist a stick in it until the bleeding stops. In one or the other of these ways, you can prevent the loss of blood until the surgeon arrives to take charge of the case.

105. Although there is no such free communication between arteries as exists between the capillaries, there is some amount of communication, and particularly in certain parts of the body.

And it is well that it is so, for it sometimes helps the surgeon to save a limb, when he could not do it if there were no communication. I have already alluded to a disease of the arteries called aneurism. An artery has three coats, one of which is a strong fibrous one. When this is thinned or ruptured, the other two coats bulge out, forming a pulsating tumour. And, as the blood is constantly pumped into this by the force of the heart, it enlarges, and at length it may burst, and the life of the patient will be destroyed by the loss of blood. When an aneurism formed in a limb, as for example in the ham, the surgeon, in former times, used to save the life of the patient by amputating the limb above the aneurism. Putting a ligature round the artery above the aneurism would of course stop the flow of blood into it; but it was supposed that the limb would die, in that case, from the want of a proper supply of blood. But it was found, at length, that this was not so; and surgeons now, in such cases, cure the disease, and save the limb too, by tying the artery. Immediately after the operation the limb is cold, and there is plainly very little circulation in it. But in a few hours the circulation becomes free, and in a little time it is as well established as ever. This is effected by the communications which exist between the branches which go off from the artery above the aneurism, and those which go off below it. It is obvious, however, that this would not be thoroughly effected if no change took place in the size of the communicating arteries. But this change does occur. Some of them become enlarged to meet the necessity of the case. This is a most interesting fact; and so is also the fact, that these communications between branches of arteries are very common in the neighborhood of those places in the body, where aneurism, from strains produced by violent and sudden motion, is peculiarly apt to appear. This same provision avails, of course, when aneurism is cured by pressure made upon the artery above it, a measure which modern surgery has found in many cases to be as effectual as tying the artery.

106. There have been great differences of opinion among physiologists, in regard to the proportionate amounts of agency that the different parts of the apparatus have in carrying on the circulation. The heart manifestly exerts the chief agency, both by its forcing and its suction power. You can get a clear idea of the manner in which it exerts these two forces in this way. Fill a ball of India rubber, to which a tube is attached, with water, and immerse the tube in water in a vessel. If you

press the sides of the ball together, some of the water is forced out into the vessel. This represents the contraction of the heart. If, now, you allow the ball by its elasticity to resume its round shape, the water rushes into it from the vessel. This represents the dilatation of the heart. The dilatation of the ball results from its elasticity; and so it is supposed by some that the dilatation of the heart results from the same cause, its contraction alone being produced by muscular action. Whether this be so or not, the dilatation is an active one, and the blood rushes into the heart from the veins by suction, as it is termed. The dilatation is so active that, as has been shown by experiments on animals, even a great amount of pressure is not able to prevent its taking place.

107. But, great as the agency of the heart is, it is not true that it is the only moving power, and that the arteries and veins are mere passive conducting tubes. There are various phenomena which show that the arteries, the capillaries, and even the lax veins, exert a considerable agency in circulating the blood. I will merely allude to some of these phenomena. Determinations of blood to particular parts show that the blood-vessels have an active agency in the circulation. In inflammation of any part, there is an increased activity of the particular portion of the circulating apparatus supplying that part. In the act of blushing, there is a local activity of the circulation somewhat independent of the heart. This is also true of the circumscribed flush of hectic.

108. There is one portion of the circulation in which the active agency of the capillaries is especially manifest. The veins, as I have told you, receiving the blood from all parts of the body, at length are all united into two veins, which empty their contents into the heart. But there is a very remarkable exception to this. The veins which collect the blood from the viscera in the abdomen unite in one large trunk, called the vena portæ; and this, instead of pouring its contents into the large vein that goes up to the heart, divides, like an artery, into branches, which take all this blood to the liver for the manufacture of bile. Fig. 24 represents this circulation of the vena portæ. 1, 1, are the veins coming from the intestines; 2 is the trunk of the vena portæ; and 3, 3, are the branches of it distributed in the liver. Now, it can not be pretended that the suction power of the heart extends its influence through the veins that bring the blood from the liver, then through the capillaries of this organ, and then through all the veins that bring the

FIG. 24.

CIRCULATION OF VENOUS BLOOD IN THE LIVER.

blood to the liver, even to the capillaries of the abdominal viscera. There must be, in this case, some propelling power in the capillaries, and some, too, also in the veins. If there were not, another subordinate heart would obviously be needed in the vena portæ, to pump up the blood from all the veins of the abdominal viscera, and then to send it through all its branches into the capillaries of the liver.

109. The veins have a less active agency in the circulation than any of the other parts of the apparatus. It is for this reason that commonly after death the veins are found quite full of blood, while the arteries are nearly empty. The apparatus of the circulation may be regarded as forming a circle of organs in this order—the heart, the arteries, the capillaries, and the veins. The blood is constantly going the rounds of this circle. It is plain that, as the apparatus is about to stop, there must be an accumulation in the weakest, least active, and most relaxed of this circle of organs. The arteries and capillaries force the blood into the veins to the last moment of life. This effect

probably extends no further than the smaller veins; but the heart, by its active dilatation, draws the blood from them into the larger veins. And as these two forces, at the two ends of the venous system, are at work up to the last moment, the whole of this system is filled with blood.

110. The fact, that the larger arteries are commonly found nearly empty of blood after death, gave the ancients the idea that air circulated in arteries, while blood circulated in veins. Hence, the name, artery, is derived from two Greek words, signifying to hold air. And hence, also, by long established custom, in common language, the blood is spoken of as running in our veins; and it would sound strangely, if, in common, and especially in poetical language, we should speak of it as running in our arteries also. Although there were from time to time some glimpses of the true idea of the circulation, it was not really developed and demonstrated till about two hundred and thirty years ago. Harvey spent eight years in maturing his ideas on the subject. When he published them, they encountered much opposition; but he lived long enough to see them almost universally received by the medical world, although the profession was in a much less enlightened state than it is at the present day.

111. I will now take you a step farther in the development of the plan of the circulation. I have said that the office of the arteries is to conduct the blood to the network of capillaries, and that in the capillaries the blood has reached its place of destination where it is to be used. The formative vessels, appended to the capillaries, take from the blood what they need for their various purposes, and at the same time there is added to the blood refuse matter from the waste of the tissues. The blood, then, is changed while it is in the capillaries. You see the change in its color. In the arteries it was red; but, after passing through the capillaries, it appears in the veins of a purple color. It is also as much changed in other properties. It is no longer fitted to nourish the body. It would even prove a poison to any organ if it should flow into its capillaries. If it should, for example, be sent to the brain, instead of bright arterial blood, that organ would cease to do its office; insensibility would ensue, and life would soon be destroyed, if the flow of red blood could not be established.

112. This purple blood, which comes back to the heart from the capillaries by the veins, must, therefore, be in some way changed to red blood, before it is again sent all over the system

through the arteries. This change is effected in the lungs. As the purple blood returns to the heart, it is sent by the heart to the lungs, in order to be exposed to the air before it is sent again over the system. For this purpose there are two circulations, and the heart is a double organ; or rather, there are in effect two hearts for the two circulations, for the two sides of the heart have no communication with each other. The apparatus for all this is very complicated, but I think it can be made clear to you.

113. I present, first, a diagram, which is intended to represent merely the *course* of the circulation, without regard to proportionate size, or to minutiæ in the arrangement of the apparatus. Let *a* represent the right side of the heart, *c* the left side, *b* the lungs, and *d* the general system of the body. The arrows show the direction in which the blood flows. In all the shaded part the blood is venous or purple, and in the part not shaded it is arterial or red. We will now take some point of beginning, and trace on the Figure the course of the circulation.

FIG. 25.

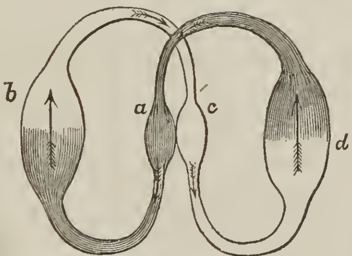


DIAGRAM SHOWING THE COURSE OF THE CIRCULATION.

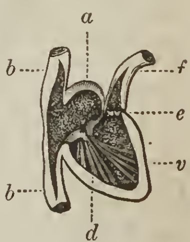
We will start at *a*, the right side of the heart. The blood received here, of a purple color, from the whole body by the veins, is sent by the heart to *b*, the lungs. Here it changes to red blood, and passes by veins back to the heart—but, observe, it is to the left side of the heart, *c*. It is now sent by this left half of the heart to all parts of the system, represented by *d*. Here, in the capillaries, it is changed to purple blood, and goes back by veins to the right side of the heart, *a*, the place where we started.

114. You see, then, that there are two separate circulations, one through the general system, and the other through the lungs alone. In both circulations the blood is sent from the heart by arteries, and is brought back to it by veins. But notice that, while in the general circulation the red blood is in the arteries, and the purple in the veins, in the circulation through the lungs it is reversed—the red blood is in the veins, and the purple is in the arteries. So, also, while the change of the blood in the capillaries of the general system is from red to purple, in the capillaries of the lungs it is from purple to red.

115. There are not only two sides or halves of the heart, separated entirely from each other, but each of these sides has two apartments, with valves or folding doors between them, so arranged that the blood can pass one way through them, but not the other. There are also valves at the beginning of the great artery of the heart, the aorta. These are so arranged that the blood can go freely out of the heart into the artery, but not a drop can get back from the artery into the heart. There are similar valves, also, at the beginning of the great artery, by which the purple blood is sent from the heart to the lungs.

116. In Fig. 26, is represented a section of the right side of the heart, for the purpose of giving you an idea of the arrangement and the relative size of the two apartments. The *auricle*, *a*, so called because a part of it has some resemblance to an ear, receives the blood from the whole system by two large veins, *b*, *b*, called the *venæ cavæ*. From the auricle it passes into the *ventricle*, *v*, which by its contractions sends it to the lungs through the pulmonary artery, *f*. The valve between the auricle and ventricle is composed of three membraneous sheets, which are held at their edges by small tendinous cords, *d*, just as a sail is held by the ropes at its corners. This valve permits the blood to pass from the auricle into the ventricle; but when it attempts to pass back from the ventricle to the auricle, it pushes back the sheets of the valve, they being prevented from going too far back by the tendinous cords. There are also valves at *e*, the beginning of the pulmonary artery, which allow the blood to pass through

FIG. 26.



SECTION OF THE RIGHT SIDE OF THE HEART.

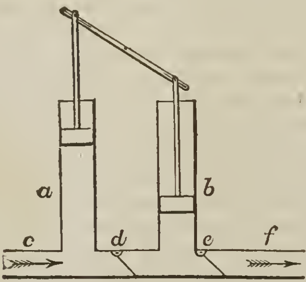
them into the artery, but no blood can pass through them from the artery back into the ventricle. I shall soon call your attention again to these different valves, that you may see more particularly their structure and arrangement.

117. The auricle and ventricle act in this way in propelling the blood. When the auricle contracts, the ventricle dilates* to receive the blood from the auricle. The valves between them are open while this is taking place. But the next moment the ventricle contracts and the auricle dilates. You at once see, that if now the valves between them should be open, the blood would be forced back into the auricle. But the membranous sheets of these valves shut upon each other as the ventricle contracts, and thus prevent the blood from going back. It therefore is discharged through the pulmonary artery, *f*, the valves there being open. And when the ventricle dilates, you can see that the blood would, from suction, enter it from the artery as well as from the auricle, if the valves at the orifice of the artery should remain open. They are accordingly shut when the ventricle dilates. You see, then, that when the auricle dilates and the ventricle contracts, the valves between the auricle and ventricle are closed, and the valves at the mouth of the pulmonary artery are open; and, on the other hand, when the ventricle dilates and the auricle contracts, the valves between them are open, and the valves of the pulmonary artery are closed.

118. Dr. Carpenter has a very good illustration of the relation of the actions of the auricle and ventricle, in a representation given in Fig. 27. The apparatus which is represented consists of two pumps, *a* and *b*, the pistons of which move up and down alternately. These are connected with a pipe, *c*, *f*, in which there are two valves, *d* and *e*, opening in the direction of the arrows. The portion *c* of the pipe represents the venous trunk discharging its blood into the heart, and the portion *f*, the artery which is the outlet for the blood. The pump, *a*, represents the auricle, and the pump, *b*, the ventricle. When the piston in *a* is raised, the fluid enters through *c* to fill it by suction, as it is termed. When, now, its piston is lowered, the fluid is forced through the valve *d* into the pump *b*, (which represents the ventricle,) whose piston is at the same time raised to receive it. And when the piston in *b* is lowered in its turn,

* This dilatation is an *active* one, as was stated in § 106, when speaking of the heart as a whole. The ventricle does not dilate because the blood is forced into it, but the blood rushes into it because it dilates.

FIG. 27.



the fluid being prevented from returning into *a*, by the closure of the valve *d*, is forced through the valve *e* into *f*, representing the discharging tube, the artery. At the same time, a fresh supply of fluid is received into *a* by the raising of its piston.

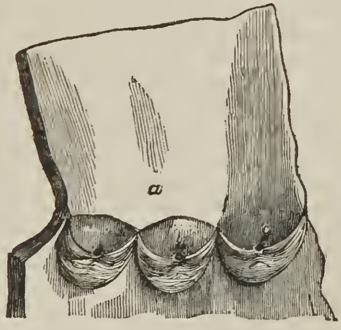
119. I have described the auricle and ventricle of one side of the heart, the right side. The left side is constructed very much in the same way. You will observe, in Fig. 26, that the ventricle is much more capacious than the auricle. The auricle is indeed the antechamber to the ventricle. The ventricle, too, you see, is much thicker in its walls. It is made very strong, because it does by far the principal part of the work. I remark here, in passing, that the size of the whole heart is about that of the closed hand of the individual.

120. I will now call your attention to a more particular view of the valves of the heart. We will take, first, the valves which are at the beginning of the aorta, the great artery of the body, going out from the left ventricle. These are very much like the valves of the veins seen in Fig. 23. There are three of them. They are like little pockets arranged around the orifice of the artery, and looking toward the tube of the artery. Of course, when the ventricle contracts, and forces the blood into the artery, these pockets are pressed by the blood flat against the sides of the artery. But when the ventricle dilates, and the blood attempts to go back from the artery into the ventricle, it gets into these pockets, and bulges them out toward the heart, and thus the mouth of the artery is closed. But you can see that if these pocket-like valves had plain curved edges, they would not effect a perfect closure. There would be a

little space in the very middle of the orifice of the artery which would be left open. This is made plain by Fig. 28, which presents the orifice of the artery with its closed valves, as it would appear seen from the interior of the heart, if the three valves had plain curved edges. There would be a space left between them. But this difficulty is remedied by a very simple contrivance. A little fleshy projection is placed upon the middle point of the edge of each valve, of such a size that the three projections together just fill the space A. When, therefore, the valves are closed, no blood can go back from the artery into the ventricle. This arrangement is shown in Fig. 29, in which the aorta, *a*, is laid open and spread out, so as to show the three valves with their projections on the edges. At *b* and *c*, are the openings of the two arteries that supply the walls of the heart

FIG. 28.

FIG. 29.



VALVES OF THE AORTA.

with blood for their growth and repair, for the heart is constructed and repaired from its own blood. The valves at the orifice of the pulmonary artery are arranged in the same manner as those which are at the orifice of the aorta.

121. The valves which are between the auricles and the

7*

ventricles I have already partially described. They are folds of strong white membrane, their edges being held by numerous small tendinous cords. And these cords are manned, as we may express it, by muscles attached to the walls of the heart. The office of these muscles is to hold on to the cords that are fastened to the edges of the valves, and prevent these sheets of membrane from flapping back too far when the powerful ventricle contracts. It is by a nice adjustment of forces that these valves act with such exactness. They are of greater extent than the valves which are at the mouth of the aorta and the pulmonary artery, and, therefore, it would not do to leave them to act alone, as those valves do, upon simple mechanical principles. The living muscular fibre must be introduced as the agent to control and regulate these principles in their application here. If it were not done, the consequence would be, that when the ventricle contracts with prodigious force, as it sometimes does when the circulation is in a great state of excitement, the light tendinous fastenings would be ruptured by the pressure of the blood upon the valves. As it is now, the strong but yielding muscular bundles, to which these tendons are attached, regulate with great exactness the closing of the valves. Even if there were no need of any regulation, by muscular action, of the movement of these valves—if the tendons would, in all cases, let the valves go back to just the right point—as they are not extensible, and have no elasticity, it is manifest that there would be more danger of rupture than there is with the present arrangement. The tendons cannot be stretched, and, therefore, under great pressure they might break. In Fig. 30 is a representation of a portion of this valvular apparatus. The engraving was made from a drawing of the part taken from the heart, and pinned upon a board for the purpose. At *m*, you see the sheet of membrane; *o*, *o*, are two of the muscles attached to the inside of the ventricle, to hold on to the tendons, *h*, that are fastened to the edge of the membrane. This membrane is now in the position that it is when the valves are open, that is, lying in a line with the little tendons and their muscles. But when the ventricle contracts, the blood, pushing against the membrane *m*, carries up the free edge to which the tendons are fastened, which, meeting the free edges of the other valves, closes with them the communication between the auricle and ventricle.

122. In looking at Fig. 26, you observe that, while there are valves between the auricle and ventricle, and at the mouth of

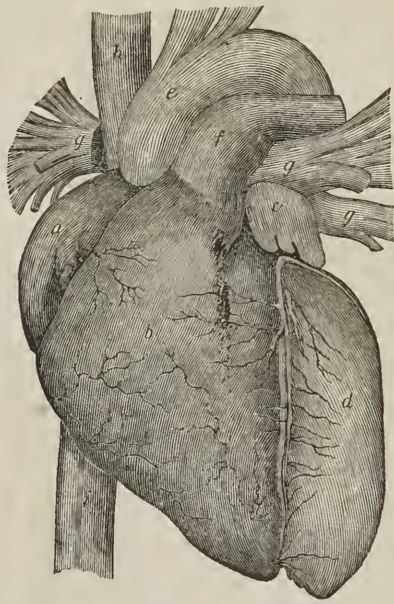
FIG. 30.

PART OF THE VAVULAR APPARATUS BETWEEN THE AURICLE AND THE VENTRICLE.

the artery going out from the ventricle, there are none at the openings of the two *venæ cavæ*, the veins that pour their contents into the auricle. Why is this? Why is there no need of valves here to prevent a regurgitation into these veins when the auricle contracts? It is because that, as the auricle contracts, there is at the same time the dilatation of the strong ventricle, making, of course, a suction in that direction so powerful as to counteract most fully any tendency to regurgitation into the veins. You readily see, that if the arrangement were reversed, and the auricle were stronger than the ventricle, then, when the auricle contracted, there would be regurgitation into the venæ cavæ, if there were no valves there to prevent it. The same remarks could be made in regard to the pulmonary veins, that pour their contents into the left auricle.

123. Having thus examined the heart in detail, you are now prepared to look at it as a whole. For this purpose, I present to you, in Fig. 31, a front view of the heart, in which *a* is the right *auricle*, receiving the purple blood from the whole body by the two large veins, *h* and *i*, called the *venæ cavæ*; *b* is the right *ventricle*, that receives the blood from the right auricle, and sends it to the lungs by the *pulmonary artery*, *f*; *c* is the left *auricle*, which receives the red blood from the lungs, by the *pulmonary* veins, *g*, *g*, *g*; *d* is the left *ventricle* that receives the blood from the left auricle, and sends it all over the body through the *aorta*, *e*. You observe, that you see but a part of the *left* auricle and ventricle, they lying partly behind the *right* ventricle. You do not see the very beginning of the

FIG. 31.



FRONT VIEW OF THE HEART.

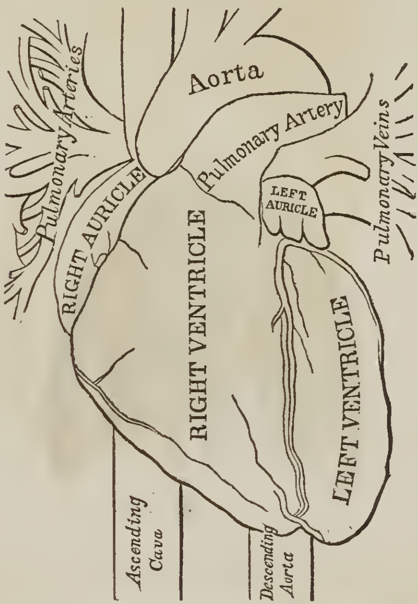
aorta, for, as it rises from the left ventricle it is at first concealed behind the top of the right ventricle and the beginning of the pulmonary artery. It then forms an arch, from which it sends forth branches to the head and upper extremities; and it afterwards passes down behind the heart, to supply with its branches the trunk of the body and the lower extremities. In the line of division between the two ventricles, *b* and *d*, you see one of the *coronary* arteries, as they are called, which, coming from the beginning of the aorta, as described in § 120, supply the walls of the heart with blood.

124. To make you quite familiar with the relations of the different parts of this complicated organ, and with the course of the blood through its different apartments, I give you, in

Course of the blood through the different cavities of the heart.

Fig. 32, a map of the heart, with the names placed upon the parts. I will describe the circulation with this map before you. The dark blood is received from all parts of the body by the *venœ cavœ*—from the parts above by the descending cava, and

FIG. 32.



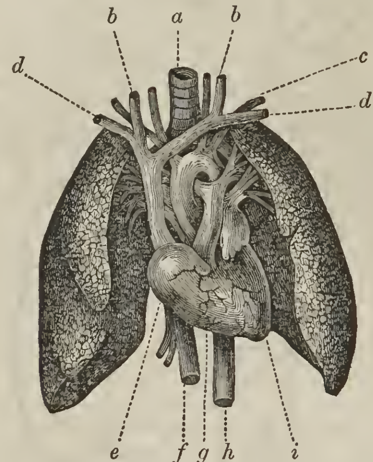
MAP OF THE CIRCULATION.

from the parts below by the ascending cava. These veins pour the blood into the right auricle. From this it passes into the right ventricle, which sends it by the pulmonary artery to the lungs. From the lungs it returns by the pulmonary veins to the left auricle. It then passes into the left ventricle, from which it is sent by the aorta to all parts of the body.

125. In Fig. 33 is represented the heart, situated between the two lungs, with the arteries which carry blood from it, and

the veins which pour their blood into it. The lungs are represented as being drawn apart to the right and left in front, so as to expose fully the heart and its vessels. The sac containing the heart, and the packing cellular tissue are removed, so as to lay the heart and its vessels bare. At *a* is the trachea or windpipe; on either side of it are the two arteries, the carotids, which go to the head; *c* is the artery which goes to the arm; *b*, *b*, are the jugular veins coming from the head, *d*, *d*, the veins

FIG. 33.



LUNGS, HEART, AND PRINCIPAL BLOOD-VESSELS.

from the arms, all empting their contents, as you see, into the descending cava; *e* is the right auricle, receiving the blood from the two cavæ; *f* the ascending cava; *g* the right ventricle, *i* the left ventricle, and *h* the descending aorta.

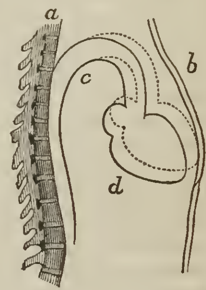
126. I have been thus particular, and have led you through some repetitions in the description of some of the figures, in order that you may get a clear idea of the complicated mechanism of the circulation. And now, perhaps, you will inquire, in what way all these four apartments of the heart contract and dilate, so as to have the organ act as one harmonious whole. You have seen how the auricle and ventricle of one

side act in relation to each other—the auricle contracts when the ventricle dilates, and the ventricle contracts when the auricle dilates. Now, the harmony of action between the two sides is preserved by having the two auricles act together, and the two ventricles act together. And this action produces two sounds, which may be heard by applying the ear to the chest of any one on the left side. The first sound is rather a prolonged and heavy one, the second is light and quick. They are very well represented by the syllables *lub-tup.* The first sound occurs when the strong action of the heart is performed, that is, when the ventricles contract. It is owing to several causes. One of these is the impulse of the heart against the walls of the chest; the cause of which I shall speak of soon. Another is the flapping together of the valves between the auricles and the ventricles, to prevent the blood from regurgitating into the auricles, when the ventricles contract to force out their contents. The light and quick second sound is caused principally by the flapping together of the valves at the mouths of the aorta and the pulmonary artery when the ventricles dilate. The pulse (which I have already remarked upon in § 100) is produced by the impulse given to the blood by the contraction of the ventricles. There is, therefore, a pulse in the arteries of the circulation through the lungs, as well as in those of the circulation through the general system. Wherever there is an artery there is pulsation.

127. The impulse of the heart against the front wall of the chest on the left side is easily explained. The heart is so enveloped by the lungs, that only a small portion of it comes near to the front wall of the chest, and such is the situation of the heart, that this portion comes to the left of the middle line of the chest. The position of the heart is an oblique one, its upper part being both farther back and more to the right than its lower part. Keeping in view this position of the heart, you will readily see how the impulse is produced against the front of the chest at its lower part. The aorta, in going from the heart, makes an arch upward and backward, to go down in front of the spine; and it is the tendency to straighten out, produced in this arch by the force of the blood thrown into it by the ventricle, that causes the throwing of the heart forward by a spring. This is easily seen as illustrated by Fig. 34, in which *a* is the spinal column; *b*, the front wall of the chest; *d*, the heart; and *c*, the arch of the aorta. When the heart throws the blood into this arched tube it tends to straighten it;

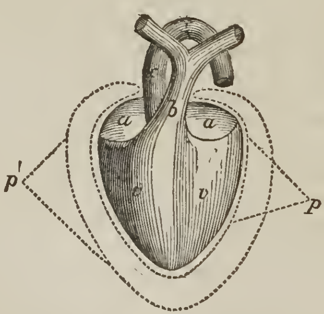
but, as the aorta is fastened to the fixed spine behind, there can be no impression made in that direction. The straightening of the arch must therefore occur in the other direction, to the front; and therefore the heart is thrown a little forward, as represented by the dotted lines. The change of position thus produced is indeed but slight, but it is sufficient to cause the impulse. The entrance of the blood into the pulmonary artery perhaps aids in the result, but not very materially.

FIG. 34.



128. The heart, as I have already hinted, is inclosed in a sac, called the *pericardium*, which, at its upper part, is fastened all around the vessels that proceed from the heart. This sac is lined on the inside by a serous membrane, which also lines the outside of the heart, being reflected over upon it from the pericardium. This membrane forms, therefore, a sac without any outlet. This is made plain by Fig. 35. In this diagram, showing the plan of the serous membrane of the pericardium, *a*, *a* are the auricles; *v*, *v*, the ventricles; *b*, *c*, the vessels proceeding from the heart; *p* the serous membrane lining the outside of the heart; *p'*, the same membrane reflected from the

FIG. 35.



PLAN OF THE PERICARDIUM.

upper part of the heart on to the inside of the pericardium. The arrangement of this membrane, as it fits on to the heart, is much like the common double nightcap, as it fits on to the head; and if it were dissected off whole from the outside of the heart and the inside of the pericardium, it would be like such a nightcap when taken off from the head—that is, a sac without an outlet. Now, this sac is kept moistened by a fluid exuding from its whole surface, so that, as that part of it which lines the outside of the heart, in the motions of that organ, rubs against that part which lines the pericardium, the lubrication prevents any injury from the friction. This lubricating fluid is continually renewed, the exhalents and the absorbents balancing each other in their action. When the exhalents secrete more fluid than the absorbents can take up, it accumulates, making what is called dropsy of the heart.

129. The heart, as you have seen, is a complex arrangement of muscles. And these muscles are wholly involuntary; that is, they are not at all under the direct control of the will. No one can by an exercise of the will make his heart beat slower or faster. As I shall show you in another chapter, this organ is kept at work by its nervous connection with the spinal marrow. It has no repose, as the voluntary muscles have, unless you call the intervals between the contractions and dilatations of its several parts intervals of repose. The amount of work which it does is enormous, if we calculate it for a lifetime. The heart of an adult beats, that is, each one of the four chambers of this organ dilates and contracts, about 70 times in a minute. This would make 100,800 times in 24 hours, 36,792,000 times in a year, and 2,575,440,000 times in a life of 70 years. In children, the action of the heart is much more rapid, and in disease it sometimes reaches in them to 160 or even 200 beats in a minute. It is thus that this organ, situated in the centre of the complicated apparatus of the circulation, labors continually, by night and by day, in keeping the blood in motion. The two circulations of the general system and of the lungs are ever going on. The blood is ever moving in all the cavities of the heart, in every artery, and vein, and capillary. It never stops till it is arrested by death.

CHAPTER VII.

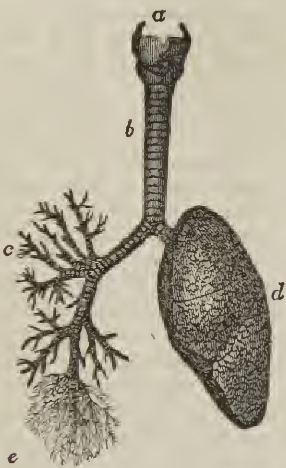
RESPIRATION.

130. You saw, in the last chapter, that the purple venous blood is sent to the lungs to be changed into arterial blood. The great object of the apparatus of respiration is to introduce the air to the blood, so that it may act upon it, and produce this change. Another object is effected at the same time, viz., the production of the voice, by the striking of the air upon the vocal chords in the larynx, as it is forced out from the lungs. This will be made the subject of a future chapter, and I propose now to show how the chief object of respiration, which is so immediately essential to the continuance of life, is secured.

131. The lungs are spongy bodies, filling up a large part of the chest, and surrounding the heart. They are in common language, the *lights;* and you can see what they are in man by observing the lights of other animals. They are composed chiefly of air-tubes, air-cells, blood-vessels, and nerves, packed together with the common packing material of the body, cellular membrane. The spongy lightness of the lungs is owing to the air-cells or vesicles. You can get some idea of the proportion of these cells to the solid part of the organs if you inflate the lungs of some animal, as the sheep or calf, by blowing into the windpipe. These cells are exceedingly minute. It is in them that the change is effected in the blood. The capillaries holding the blood branch out on the walls of the cells, and the blood is acted upon by the air through the pores of the vessels. The object, therefore, of respiration is to introduce the air freely into these cells. The air enters through the windpipe, and this branches out into tubes called bronchi, which divide and subdivide, till they become very minute, and then end in the air-cells. These cells are estimated to be about the $\frac{1}{100}$th of an inch in diameter. Some calculations have been made in regard to the extent of surface which they would all make if they could be spread out in one sheet. There is of course no great accuracy in such calculations; but we can readily see that the aggregate surface must be immense, and, therefore, the blood is thus very extensively exposed to the action of the

air. In Fig. 36 is represented the lung of one side, *d;* the branches of the bronchi of the other lung, *c*, at the lower part of which, *e*, they are represented as they branch out minutely to open into the air-cells; *b* is the trachea or windpipe, and *a*

FIG. 36.



LUNGS AND AIR-TUBES.

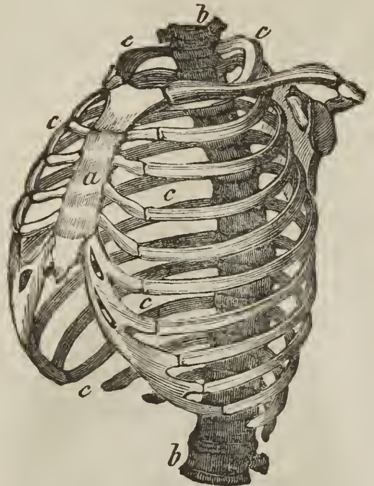
is the larynx at the top of it. It is through a chink called the glottis, in the larynx, that all the air passes as it goes into and out from the lungs. This will be particularly described hereafter.

132. In Fig. 33, in the last chapter, you see represented the relative situation of the heart and lungs, the lungs being somewhat separated, however, from the heart, to the right and left, in order to show that organ fully. In their natural position they are close to the heart, and cover up all of it, except a small portion in front and to the left side, where its beating is so plainly felt. Both the heart and the lungs are suspended in the chest to the upper part of the walls of this cavity, and are fastened also to the spinal column in the rear. The large vessels of the heart, and the bronchi of the lungs, serve as the princi-

pal means of suspending these organs, as you can readily see by the Figure. The lungs are covered by a white, shining membrane, which also lines the inside of the walls of the chest (§ 67.) called the *pleura.* This is always kept lubricated by a watery fluid, so that, as the lungs expand and the chest moves, the friction will be attended with no inconvenience or injury. You may perhaps ask why, as the lungs follow the walls of the chest in its expansion, they could not have been fastened to these walls throughout their whole surface. The principal reason probably is that, if this were the arrangement, the intimate vascular connection, which would in this case exist between the walls of the chest and the lungs, would expose the delicate texture of these organs more frequently to injury from external violence. As it is now, the effusion, or the inflammation, consequent upon a blow on the chest, is not apt to affect the lung in the neighborhood, because it has no *direct* connection with it by nerves and blood-vessels.

133. You are now prepared to see by what mechanism the air is alternately introduced to and expelled from the lungs. The chest incloses a large space, which can be made much greater by certain movements of its walls. It is this expansion of the cavity of the chest, effected by certain muscles, which, by creating a vacuum, causes the air to rush into the chest through the trachea, just as air rushes into the bellows when the space within is expanded by the separation of its walls. That you may understand how the expansion of the chest is effected, I now proceed to describe the chest. In Fig. 37 you see the framework of the chest. At *b*, *b*, is the spinal column, the grand pillar supporting the walls of this cavity. The ribs, *c*, *c*, go from this with a large curve round to the breastbone, *a*, in front. The ribs, however, do not join directly with the breastbone, but there are cartilages intervening, as you observe in the Figure. The collar-bone goes from this breastbone across to the top of the shoulder. The ribs are twelve on each side. The lowest two are attached only to the spine, and are called floating ribs. The whole is so constructed as to allow a very considerable expansion of the cavity. As, in effecting this expansion, the ribs are carried upward and forward with the breastbone, the ends of the ribs at the spine move but very slightly. As the chest is kept in constant motion, lightness in its walls is an object of some importance; and, at the same time, it is necessary that the structure should be a strong one, in order to guard effectually the lungs from injury. Both of

FIG. 37.

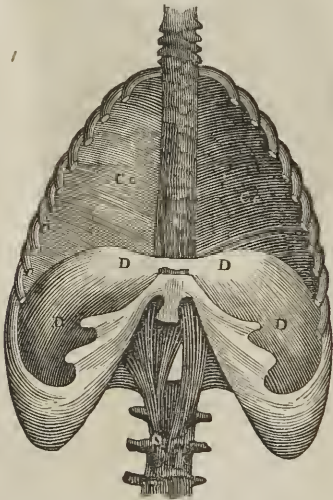


these objects are secured, by having the walls in front and at the side composed of so many bones, well bound together by the muscles which move them. If these bones were all in one, it would be necessary that it should be quite thick, to answer as a defence, and then it would be a heavy and unwieldy thing to move. The cartilages which connect the ribs to the breastbone are a great safeguard. They give elasticity to the structure as a whole, and the ribs are not very liable to be broken, because of the yielding of the cartilages with which they are connected.

134. This framework is filled out with connecting material, chiefly muscles, which effect the expansion of the chest in inspiration. First, there is a large expanse of muscle and tendon stretching across the lower part of the chest, separating its contents from the contents of the abdomen below. The edge of this muscle, which is called the *diaphragm*, is fastened to the spine behind, to the end of the breastbone before, and all around the lower ribs. It is arched upward; and against its concave surface press upward the liver and stomach, while the lungs and

the heart press downward against its convex surface. The diaphragm is represented in Fig. 38. The ribs are cut away in front, so as to give a front view of the cavity of the chest, C, c, the lungs and heart being entirely removed. D D is the diaphragm, very high in the central portion, which is tendinous, but descending very low at its edges at the sides and in the rear.

FIG. 38.

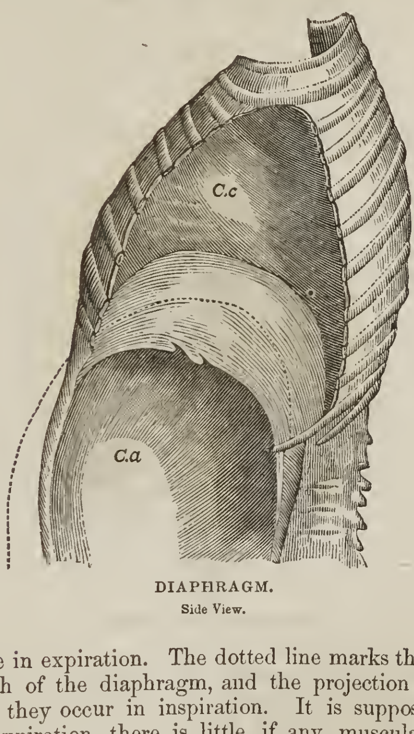


DIAPHRAGM.
Front View.

135. You can see that, if all the muscular fibres in the diaphragm contract, the arch will be flattened, and thus the room in the chest will be enlarged. To occupy this new room thus made, the air rushes in through the windpipe. This is *inspiration.* In *expiration*, the reverse movement takes place—the arch of the diaphragm rises, and, compressing the lungs, forces the air out of them through the trachea. In inspiration, as the diaphragm is flattened, it pushes down before it the stomach, liver, &c., and hence the pressing out of the abdomen, which is so sensibly felt, if the hand be placed upon it during the act of inspiration. In expiration, on the other hand, the

abdomen retreats inward. These two opposite states of the arch of the diaphragm, and of the walls of the abdomen, are represented in Fig. 39. It is a side view, the ribs being cut away. C c is the cavity of the chest, and C a, the cavity of the abdomen. The diaphragm and the abdomen are represented

FIG. 39.



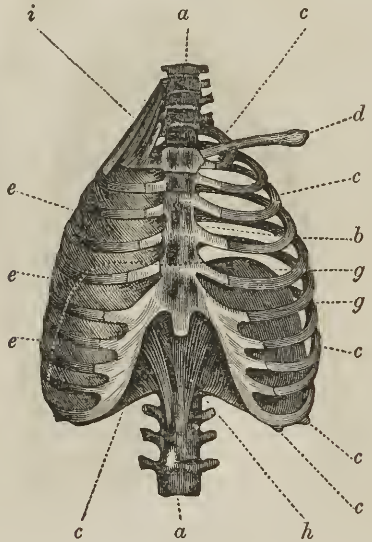
DIAPHRAGM.
Side View.

as they are in expiration. The dotted line marks the flattening of the arch of the diaphragm, and the projection of the abdomen, as they occur in inspiration. It is supposed that in ordinary expiration, there is little, if any, muscular action—that, as the diaphragm, which in inspiration pushed down the stomach and liver, and thus thrust out the walls of the abdomen, ceases to contract and relaxes, the mere elasticity of the parts below, and especially of the abdominal walls, restores the former condition of things, and so the diaphragm is carried upward, and expiration results. When, however, the ex-

piration is at all forcible, it is produced in part by the action of the muscles of the abdomen and some of the muscles about the chest.

136. While this dome-shaped muscle, the diaphragm, is the principal agent by which the chest is enlarged, there are other muscles which do the same thing in another way. In Fig. 40, *a* is the spine; *c*, *c*, *c*, the ribs; *b*, the breastbone; *d*, the collar-bone; *g*, the diaphragm. You observe, on the right side

FIG. 40.



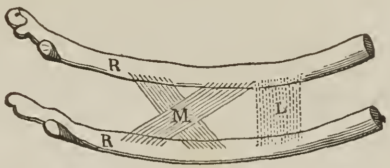
WALLS OF THE CHEST.

of the chest, certain muscles, *i*, extending from the spinal column in the neck to the first rib. When these contract, the effect will be to raise this first rib, and all the others, being attached to it, of course follow. And, as the ribs, as you see in Fig. 37, slant downwards from the spine toward the front, the result will be, that all the ribs will be carried together forward and upward. This result is the more effectually secured by muscles which pass from rib to rib, as seen at *e*, *e*, *e*, *e*. In this Figure, the ribs, *c*, *c*, *c*, are left bare on the left side, to show

the arch of the diaphragm, *g*, the dotted line indicating it on the right side.

137. There are two layers of muscles connecting the ribs, the fibres of which cross each other, as represented at M, in Fig. 41. R R are parts of two ribs. The spaces between the

FIG. 41.



ribs are filled with muscular fibres, arranged as represented in in the Figure. If the fibres were straight, as at L, they could not bring the ribs as near together as the oblique fibres do. For, as muscles can not shorten themselves, at the farthest, more than one-third of their length, the straight fibres could bring the ribs only one-third nearer together, while it is obvious that the oblique fibres, with the same contraction, can do much more than that. These muscles between the ribs not only, then, help to raise all the ribs as a body, as mentioned in § 136, but they bring each rib nearer to the one above it. This increases the expansion of the chest, especially as the ribs are so joined to the spine, that if a rib be moved upward, it must be carried outward as well as forward. You can see, then, that by the operation of these muscles in the neck and between the ribs, the diameter of the chest will be increased from front to rear, and also from side to side.

138. The chest is expanded, then, in two ways—by flattening the arch of the diaphragm, and by raising the ribs. In ordinary quiet respiration, this expansion is effected chiefly by the diaphragm. But when there is a call for more active respiration, as in violent exercise, the muscles which raise the ribs act strongly, and hence the heaving of the chest, as it is called. Their action is violent when from disease, as in asthma for example, it is difficult to introduce sufficient air into the lungs.

139. The lungs, heart, &c., accurately fill the chest in all the variations of size to which its cavity is subjected in respiration.

For, when the chest is expanded, the spongy lungs swell out to follow its walls, and the air rushes in through the trachea to fill the expanding air-cells. If, now, there were an opening through the walls of the chest, communicating with the outside of the lung, when the chest expanded, the air would rush in at this opening as well as through the trachea, and the lung would be compressed in proportion to the freeness of the opening. This has sometimes occurred from disease and from wounds. If a free opening were made at the same time in both sides, both lungs would be compressed, and death would be produced by suffocation, as really as if some obstruction in the windpipe prevented the air from entering the lungs.

140. I have said that the change in the blood, from purple to red, is effected in the air-cells. The blood and the air are brought very near together for this purpose; and yet they are kept entirely separate, except when, from disease, the blood escapes into the air-cells and air-passages, and is then expectorated mingled with air. It is supposed that the air in the cells acts upon the blood through the pores of the vessels containing it, which branch out on the walls of the cells; for if dark venous blood be inclosed in a bladder, the air will act through the pores of the bladder, and gradually change the outer portion of the blood to a red color.

141. These air-vesicles, then, do an important work. The change which is effected in them is immediately essential to the continuance of health, and even of life. If the air be in any way shut out from them death occurs at once. And so important is it that they should do their work well, that extraordinary provisions are made to secure an abundance of room for them under all circumstances. For the cavity of the chest, as you have seen in this chapter, can be expanded to a very great extent. It would indeed be difficult to conceive how a greater range of expansion could be secured. As the air-cells are called upon to do more work at some times than at others, there are special provisions for a larger dilatation of the chest than is required in ordinary quiet respiration. Thus when, from violent exercise, the blood is coursing rapidly through the lungs, and more air is therefore needed to change it to red arterial blood, the chest is largely expanded by calling into action muscles, which do but little, if any thing, in ordinary breathing.

142. As the apparatus of respiration is so especially arranged to secure room for the lungs under all circumstances,

it must be very deleterious to the health of the body to interfere with this arrangement. If the expansion of the chest in breathing be limited by any pressure, every air-cell must be embarrassed in doing its part in changing the blood. Either all of them must be unduly contracted, or some of them must become obliterated, so that there will not be as many vesicles as there should be. In either case, the organ is disabled in proportion to the amount of the compression. The blood is not as good as it would be if there were enough vesicles, and they could perform their work without constraint. The vigor of the system is therefore lessened. And, besides, the lungs themselves are especially liable to disease from this unnatural confinement.

143. Much injury is undoubtedly done to the lungs that are thus confined, when any strong exercise is taken. If the chest be left free to expand to its fullest extent when occasion requires, this injury is avoided. For when the strongly and rapidly contracting heart pumps the blood in such quantities into the lungs, the widely expanding chest draws in the due amount of air to change the extra amount of blood. All the air-vesicles are ready to do their duty, and, therefore, no violence is done to the delicate texture of the lungs. But if these organs be compressed, the dilatation of those vesicles that are not obliterated, in the midst of the commotion of the difficult respiration, is very unequally effected, and some of them are stretched beyond their proper dimensions. At the same time, the blood must be here and there obstructed in its passage through the lungs, producing what is termed congestion. And if this violence be repeated from time to time, permanent disease will after a while be the result.

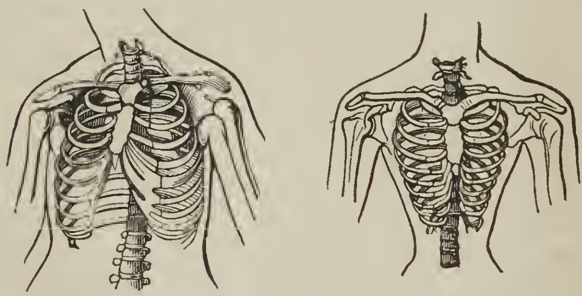
144. From the considerations in the two last paragraphs it is manifest, that the interference with the due expansion of the lungs, which so commonly results from the modes of dress in the female sex, must be one of the prominent causes of consumption, to say nothing of other diseases arising from this cause. This interference is effected in two ways—chiefly by compression of the chest directly, but also by the pressure which the load of clothing hanging from the girt waist must make upon the upper part of the abdomen. This latter cause interferes with that forward movement of the abdomen which, as you saw in § 135, is necessary to the flattening of the arch of the diaphragm in the act of inspiration. The extent to which compression of the chest is sometimes carried is seen by

comparing the two outlines in Fig. 42. One is an outline, the Venus de Medicis, the universally recognized beau ideal of beauty of form in the female, and the other is an outline

FIG. 42.

of the form of a lady with an artificially small waist. In Fig. 43 is represented the framework of the chest of its natural size, and as it is sometimes contracted by fashion. The Figures

FIG. 43.



representing the contraction of the chest may appear at the present time as caricatures, for a very small waist is not considered now to be as essential to beauty in the female form, as it was twenty-five years ago. The truth, as uttered by medical men, has had some effect. But the evil is remedied only in

part. The chest of the female is still too much begirt, in obedience to the tyranny of fashion, to allow of the free expansion, to secure which such special pains are taken by nature. The evil begins in childhood. The chest is moulded during its growth to the shape which fashion prescribes. It could not be done after the chest has attained its full size. The torture of the compression necessary to do it could not be endured. In childhood, therefore, while the boy's chest is left to grow in its natural shape and dimensions, the girl is begirt so tightly as to embarrass her respiration, because nature is too ungenteelly large in her patterns to suit her case. The subject is an important one; but as this book is not designed to treat of hygiene, I can not go into it further.

145. It is the interruption of the change which is effected by the air upon the blood in the lungs, that produces death in drowning. The very common supposition, that considerable water gets into the lungs in drowning, is erroneous. Very little water ordinarily gets in—not enough to occasion any embarrassment. The difficulty is, that the air is kept out, and not that the water gets in. The drowning person makes attempts to inspire, but the moment that the water reaches the epiglottis, the door of the windpipe, it causes at once, by its irritation, a spasmodic closure of the epiglottis, so that almost no water is introduced. In the mean time, the purple blood continues to be thrown by the right ventricle of the heart into the lungs. But the little air contained there soon parts with its oxygen; and then the change in the blood ceases to occur, and dark blood is sent from the lungs to the heart, and thence to all the organs. These can not go on to do their duty without the stimulus of arterial blood. The brain, therefore, gives out, and there is insensibility. The muscles cease to act, and all motion is gone. If a good supply of arterial blood could be furnished to all the organs until breathing could be again commenced, life would be preserved. And there is provision for such a supply in certain animals that can remain under water for some time. For example, in the whale there are large reservoirs for containing arterial blood, which can be used for the supply of the organs while he remains under water. When the supply begins to be exhausted, the animal of course has those uncomfortable sensations which a predominance of purple blood is so apt to produce. He manifests his uneasiness by his puffing and blowing, as he rises to the surface, to get a fresh supply of air, and with it a fresh supply of arterial blood in the reservoirs.

146. The apparatus of respiration varies in different animals. It appears in three forms—lungs, gills, and tracheæ or air-tubes. The gills of the fish are arranged in fringed laminæ, in order to present by all its minute divisions a large surface; and these delicate organs are covered with a lid to protect them from injury. The blood-vessels which contain the blood to be changed branch out on the surface of the fringes of the laminæ, just as the blood-vessels in lungs branch out on the surface of the air-vesicles. The air which is to change it is mingled with the water. It acts upon the blood, as the water containing it, after being taken into the mouth of the fish, passes out through these laminæ, as through a sieve. That the air in the water is the cause of the change can be proved by experiment. If a fish be placed in a vessel with its orifice closed, so that no air can enter, it will soon die from suffocation, because the air in so small a portion of water is soon used up. Although the fish can not with his gills use air that is not mingled with water, it is supposed that it is merely because the gills soon become dry when exposed to the air, and that the air would act on the blood in the gills if they were only kept moist. Indeed, in the land crab, that has the power of living for some time out of the water, it has been found that there is a gland in the gill-chamber which furnishes a secretion to keep the gills moist. Gills differ much in their shape and arrangement in the various aquatic animals. In Fig. 44 is represented the arenicola or lob-worm. Here, the gills are in the form of tufts arranged along the outside of the body. They take a somewhat similar form in the larvæ of many aquatic insects, as seen in Fig. 45. A large surface is presented to the air contained in the water by the delicate and beautifully arborescent gills of these animals. In insects, we find the respiration effected by *tracheæ* or air-tubes. These go into all parts of the body, and the air contained in them acts upon the blood in the vessels which branch out upon their walls. The insect, therefore, has no distinct respiratory organs situated in any one part of the body, but the

FIG. 44.

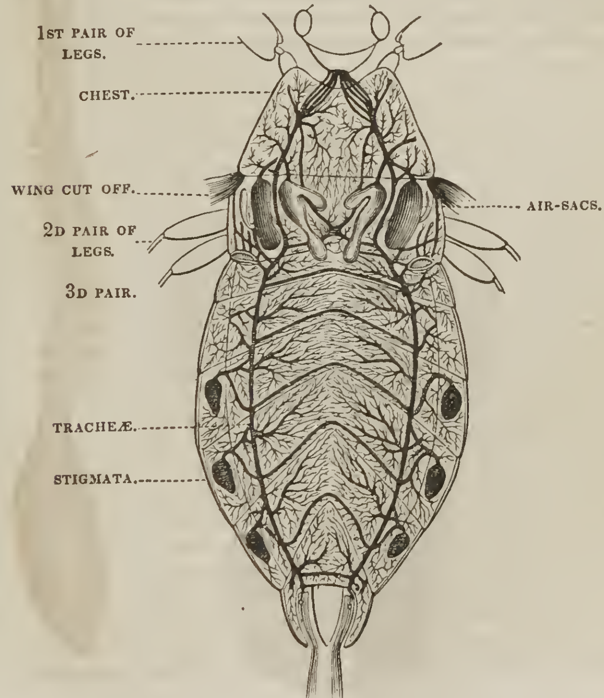
LOB-WORM.

air is carried into every part. This seems to be necessary on account of the feeble circulation in the insect. The tracheæ which, as Cuvier says, conduct the air in search of the blood, as the blood has no means of travelling in search of air, open on the surface by *stigmata*, as they are called, which are of various shapes and number in different insects. In the grasshopper there are twenty-four, arranged in four rows. You can kill an insect by suffocation by simply covering the stigmata with varnish. In Fig. 46 are represented the tracheæ in an insect, the nepa or water-scorpion. The tracheæ, as you see, send branches out in every direction, so that air is introduced

FIG. 45.

LARVA OF THE MAY-FLY

FIG 46.

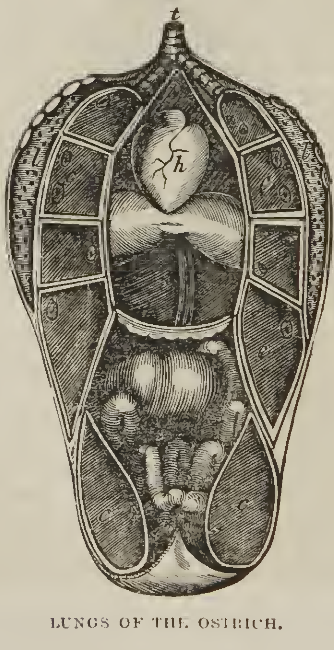


RESPIRATORY APPARATUS OF THE WATER-SCORPION.

into every part of the body. There are lungs, so to speak, everywhere in the insect.

147. The apparatus of respiration is largely developed in birds for two objects—to provide for the extensive change in the blood which is required by their great activity, and to give lightness to the body. To secure these objects there are air-sacs connected with the lungs, and located in different parts of the body; and in birds that fly rapidly and are long upon the wing, these sacs are very extensive, and even many of the bones are made hollow, and are connected with the air sacs. By this arrangement, the air is introduced extensively to the blood in the capillaries on the walls of these sacs, and at the same time the body is made very light. And the heat generated by the effort of flying must expand the air in the air-sacs and swell them out, and thus make the body lighter. In Fig. 47 is seen this arrangement of air-sacs in the ostrich. The lungs, *l*, *l*, are quite small, but the air-sacs, *c*, *c*, *c*, are very large. The orifices by which they communicate with the lungs you see

FIG. 47.



LUNGS OF THE OSTRICH.

in the Figure. In birds of great powers of flight, the air-sacs are much more extensive. This arrangement of air-sacs in different parts of the body of the bird bears some analogy to the tracheæ distributed in the bodies of insects.

148. You have seen that the object of the apparatus of respiration is to change venous blood into arterial, and you have also seen how the air is introduced to the blood in order to effect this change. And now the interesting inquiry arises, what are the actual changes which occur, both in the blood and in the air, in the lungs. If you take a tumbler filled with lime-water, and breathe into it through a tube, the lime-water will become turbid, and will soon deposit a sediment. This is chalk, or carbonate of lime, formed by the union of the carbonic acid gas exhaled from the lungs with the lime in the lime-water. Whence comes this carbonic acid gas, and how is it formed? In order to answer this question satisfactorily, we must look at the chemical constitution of the air which we breathe. It is composed of two gases, oxygen and nitrogen. In every 100 parts of common air, there are 79 parts of nitrogen and 21 of oxygen. It is found that the oxygen is that constituent of the air which is necessary to life. If an animal be placed in a closed jar filled with common air, he will soon die, and the oxygen will be found to have disappeared, while the nitrogen remains very nearly the same in amount. If, now, you place an animal in a jar of nitrogen, and another in a jar of oxygen, the one in the nitrogen will die immediately, while the other will be very lively until the oxygen is mostly used up by his lungs. The animal in the pure oxygen will breathe at first more rapidly than the animal in the jar of common air; and it is thought that oxygen is too stimulating for the lungs, and therefore needs to be diluted with the nitrogen, as it is in the air that we breathe.

149. In the case of both the animal in the jar of air, and that in the jar of oxygen, carbonic acid is found to have taken the place of the oxygen which has disappeared. This gas is made by a union of oxygen with carbon or charcoal. It was formerly supposed that this union is effected in the lungs—that carbon is thrown off from the venous blood in the lungs, and that the oxygen of the air there unites with it, and so carbonic acid appears in the air expired from the chest. But it has been discovered that the exchange is made in a different manner. It is not made in the lungs. The oxygen is absorbed by the blood, and goes with it to the heart to be sent all over the

system. And it is in the capillaries that the oxygen unites with carbon to form carbonic acid. The union takes place while the blood is changing from arterial to venous, and is an essential part of the change. The carbonic acid thus formed in the capillaries, is brought back to the heart in the venous blood, and is discharged from the system in the lungs. That the change takes place as stated has been abundantly proved in various ways. It has been found by experiments which I will not detail, that carbonic acid exists in considerable amount in venous blood; while, on the other hand, there is much oxygen in arterial blood. The plain inference from this is, that oxygen unites with the blood as it passes through the lungs, goes with it to the capillaries, and there unites with the carbon, giving us the carbonic acid which we find in the blood in the veins, after it has passed into them from the capillaries. It has been found, also, that if frogs or other cold-blooded animals be placed in hydrogen or nitrogen, (gases which produce no injurious effect on them,) they will give off for some time nearly as much carbonic acid as they would have done in common air. In this case, as no oxygen is introduced into the lungs, the carbonic acid can not come from any union effected in these organs between carbon and oxygen, but it must be discharged by exhalation from the blood as it is passing through the lungs. Of course the discharge of the carbonic acid ceases after a little time; for, there being no new supply of oxygen by way of the lungs, as there is when the animal is breathing common air, there can be no new formation of carbonic acid. But even cold-blooded animals can not live in these gases for any great length of time, although they are not positively deleterious to them, for oxygen is needed for the continuance of their functions. And in the warm-blooded animals, a constant supply of it is necessary—they will die if cut off from this supply even for a short time.

150. The change which takes place in the blood, as it passes through the lungs, occurs to some extent when the blood is exposed to the air in any way. Thus, if blood be drawn from a vein into a bowl, the surface of it becomes red by the action of the air upon it. Carbonic acid is discharged from it, and the oxygen of the air takes its place, uniting with the blood, just as the process occurs in the lungs. A larger part of the blood will be thus changed, if it be shaken so as to expose more of it to the air. The change takes place to some extent even if a membrane be interposed between, as when the blood

is inclosed in a bladder. The oxygen of the air, in this case, is introduced through the minute pores of the bladder, and the carbonic acid gas escapes through them. Precisely in this way is the change effected in the lungs, as already stated in § 140. The blood is separated from the air by being confined in blood-vessels, and the air in the vesicles acts upon it through the minute pores of these vessels. And, as the blood is divided into innumerable little streams, every part of it is acted upon by the air in the vesicles. Though the texture of the lungs is exceedingly delicate, and the separation between the air and the blood is almost as nothing, yet the blood is confined to its limits, even though it courses through these organs with great rapidity, and it never mingles with the air except as a consequence of actual disease.

151. The quantity of carbonic acid gas discharged from the lungs in the course of twenty-four hours is very great. Many experiments have been tried and calculations made to ascertain its amount, and I am within bounds when I state, that there is at least three-quarters of a pound of charcoal in the carbonic acid thrown off from the lungs of a common-sized adult in the course of twenty-four hours. This gas is a deadly poison. When accumulated in a considerable amount, as when charcoal is burned in an open furnace in a close room, it may prove immediately destructive to life. And in the very prevalent neglect of ventilation, the frequent accumulation of this gas from the respiration must prove more or less injurious to the health. Whenever the proper amount of oxygen gas is withheld from the lungs, and carbonic acid takes its place, the quality of the blood is impaired from incompleteness in the change effected in the lungs, and the vigor of the body must in this way be lessened, to say nothing of the deleterious influence of this gas upon the nervous system. Though the results are not immediate and palpable, great injury is continually done to the health of multitudes by the accumulation of this gas, in small close apartments, and in crowded assemblies. A congregation of twelve hundred people in two hours throw off from their lungs an amount of carbonic acid that contains seventy-five pounds of charcoal. And yet little pains is commonly taken to carry off this vast quantity of poisonous gas, and replace it with pure air.

152. As so much oxygen is absorbed in the lungs of all animals, and so much carbonic acid is thrown out from them, the inquiry arises how the air is replenished with oxygen, and is

cleared of the carbonic acid which is thus so largely mixed with it. It is found that this is done, to a great extent at least, by the leaves of plants. The process which goes on in these lungs, as they may be called, of the plants, is quite the reverse of that which is going on in the lungs of animals. The carbon of the carbonic acid which is thrown off from the lungs of animals is absorbed by the leaves of plants, and the leaves replenish the air with the oxygen, which is so constantly and abundantly absorbed in the lungs of the animal creation. Thus, the animal and vegetable kingdoms are sources of supply to each other. But it may be thought that there would be apt to be a surplus of oxygen in the atmosphere in warm climates, where the vegetation is so luxuriant; while, on the other hand, there would be an accumulation of carbonic acid gas in the colder regions. This would be so, if the air were not so movable that the equilibrium is readily secured in either case.

153. It is an interesting fact, that the presence of light is necessary to the process which I have described as going on in the leaves of plants. Each leaf may be considered as a laboratory, and the light as the chief agent in effecting the chemical changes that occur in it. And it is found that no artificial light can do the work. It is only the light of the sun that is competent to this chemistry. And as these innumerable laboratories are everywhere at work, absorbing the carbon and exhaling the oxygen, to purify the air rendered noxious by the laboratories of the animal creation, we must confess it to be a mystery as to how the chemistry of the lungs of animals, and that of the leaves of plants should be kept so nicely balanced. The balance is so strictly maintained, that the chemical composition of the air is always found to be almost exactly the same.

154. The heat of the body is maintained by the union which takes place in the capillaries between the carbon and hydrogen of the system, and the oxygen which is introduced into the blood through the lungs. It is a process analogous to combustion. When carbon or charcoal is burned in a vessel containing air, the oxygen disappears, for it unites with the carbon, and carbonic acid gas, therefore, appears in its place. The same union occurs in this case between carbon and oxygen, as we find occuring in the capillaries. A sort of combustion, then, is going on in every part of our bodies. And, as heat is evolved in the one case, so it is in the other. The same can be said of the burning of *hydrogen* and oxygen together. Heat is caused by the union thus produced between them, and

so it is when they unite in the body. The water which is exhaled from the lungs comes from this union of oxygen and hydrogen. It was formerly supposed that the union between the oxygen and the carbon and hydrogen takes place in the lungs, and that the heat is made there, and then is distributed over the whole system. But it was objected to this supposition, that it made the lungs a sort of furnace for the rest of the body, and that, if the supposition were correct, there ought to be a much higher degree of heat in these organs than anywhere else, which is not the case. Ingenious theories were broached to get over this difficulty; but it was at length discovered that the union between the oxygen and the carbon and hydrogen occurs in the capillaries of the body, instead of the lungs, and that the combustion, therefore, that produces the heat is everywhere, instead of being in one locality.

155. The fuel for this combustion comes from three sources. One of these is the waste of the tissues. This furnishes a considerable amount of the carbon and hydrogen for the union with the oxygen, in all animals that are subjected, from their activity, to much wear and tear of the system. I barely allude to this now, and shall enlarge upon it soon. Another source of the fuel for combustion is food. The oily, sugary, and starchy kinds of food are devoted in a great measure to this particular purpose. These furnish a sort of floating fuel, as we may express it, which is carried about in the blood. Hence, we see, that our diet must necessarily be varied according to the weather and the climate. In cold weather, the heat of the body is more rapidly abstracted than in warm weather, and, therefore, we need then more of that food which affords a supply of carbon and hydrogen. And so as to climate. The enormous quantity of oily food often consumed by inhabitants of very cold climates is used up by being burned, as we may say, in the capillaries to keep up the animal heat. Of course, keeping the body warm by fire and clothing relieves from the necessity of taking any large quantities of fuel-making food. Still, under the most favorable circumstances in this respect, there is a need of variation in diet to suit the weather and the climate, and we make this variation for the most part instinctively. Indeed there is a marked provision in nature for it. I will mention but a single example of this provision. While there is a large amount of fat in the bears and seals and whales which afford food for the Esquimaux and Greenlander, there is very little in the animals which furnish a part of the diet of the

inhabitants of tropical climates. Another source, still, of animal heat is the store of fat which is laid up in the body. One design of this accumulation of fat in different parts of the body seems to be to provide for the heat when other sources fail. Thus, when disease destroys the appetite, and thus cuts off the supply of food, the fat wastes away, or rather is burned up, to keep up the temperature of the body. The fat is the great means of maintaining the requisite temperature when hibernating animals become torpid for the winter. They become very fat in the autumn, before crawling into their winter quarters, and in the spring they come out very lean, their fat having been consumed in keeping up the low degree of temperature required during this time.

156. As the amount of heat produced, when charcoal is burned in air, or when oxygen and hydrogen are burned together, depends upon the quantities of carbon and hydrogen that unite with the oxygen, so, also, the degree of animal heat depends upon the quantities of carbon and hydrogen that unite with the oxygen in the capillaries. This may be illustrated by referring to the effects of exercise on the heat of the body. When the circulation is quickened by exercise, the blood passes more rapidly than usual through the lungs, the respiration is consequently quickened, more air is introduced into the lungs, and therefore oxygen is more rapidly absorbed by the blood. At the same time, the action of the muscles effects a waste in their structure by the wear and tear, so that more carbon and hydrogen are ready to be released to be united with the increased oxygen. Hence comes the heat produced by exercise. So, too, those animals which are the most active, ordinarily have the most animal heat, and have the most extensive respiratory apparatus, so that there may be a free supply of absorbed oxygen to unite with the carbon and hydrogen of the changing tissues. It is in birds and insects that this union takes place most largely, and in them, therefore, the respiratory apparatus is very largely developed. This is to be attributed to their muscular activity, which produces so much waste matter that must be removed from the system. Cold-blooded animals, on the other hand, are very inactive. There is not, therefore, much wear and tear of the tissues. There is comparatively little waste, therefore, to be thrown off. And so but little oxygen needs to be introduced into the lungs, and consequently little heat is generated. To realize fully the contrast between the warm and the cold-blooded animals in these respects, observe, as

the representative of the one class, a canary bird, and a frog as the representative of the other. The frog is generally quiet, and only now and then takes a leap or croaks; but the bird is ever in restless motion, and sings much of the time with all his might. The bird is warm with the heat generated by the constant union of oxygen with carbon and hydrogen in its capillaries; but the frog is nearly as cold as the water in which he is immersed. The bird breathes rapidly, to let the oxygen of the air largely into his lungs; but the frog scarcely seems to breathe at all, so scanty is the supply of oxygen which he needs.

157. Cold-blooded animals are very nearly of the same temperature with the substances that are around them; but warm-blooded animals have a certain degree of temperature, which they maintain with considerable uniformity under all variations of temperature in the atmosphere. This in man is about ninety-eight degrees of Fahrenheit. This, you observe, is above the temperature of the surrounding air, except in exceedingly hot weather. The human body is therefore always giving off heat. Indeed it is essential to comfort that it should part with considerable heat, for any near approach of the atmosphere to ninety-eight degrees produces an uncomfortable sensation of heat. But the amount of heat which the human body can bear for a short time is much greater than the facts above alluded to would lead us to suppose. It was long taken for granted, that it could not safely bear, even for a short time, a heat much higher than that which is endured in hot climates. The truth on this subject was at length discovered by accident. Two Frenchmen were employed by government, in 1760, to devise some method of destroying an insect which infested the grain at that time. The result of their experiments was the discovery, that by subjecting the grain to a certain degree of heat in an oven the insect was destroyed, and the grain not injured. While they were trying their experiments, a girl offered to go into the oven and mark the height of the mercury in the thermometer. It stood at 260°; and, after remaining there for ten minutes, which she found that she could do without any great inconvenience, she marked it at 288°, that is, 76° above the boiling point of water. These facts led to the famous experiments of Dr. Fordyce and Sir Charles Blagden, in England. With wooden shoes, tied on with list, they went into a room in which the thermometer showed the air to be at 260°. Their watch chains were so hot that they could scarcely

touch them, and eggs were roasted hard in twenty minutes, and beefsteak was cooked in thirty-three minutes. And yet the same air that produced these results was breathed by them with impunity, and it raised the heat of the body but very little. The air which was breathed out from the lungs was so much cooler than the air of the room, that it was refreshingly cool to the nostrils, and to the fingers as they blowed upon them. In such cases, the evil effects of the heat are prevented chiefly by the great amount of perspiration that occurs, the vaporization of this abstracting the heat, which would otherwise accumulate in the body and produce disastrous results. The exhalation from the lungs, also, has some influence.

158. In the state of hibernation, to which I have several times referred, the torpidity varies in degree in different animals. In cold-blooded animals, respiration and circulation may cease altogether in this state. In them the movements of life are often, perhaps we may say generally, as fully suspended as they are in the seed that is kept from heat and moisture. They may be preserved in this state for a long time and yet revive. Serpents and frogs have been kept in an ice-house for three years, and then have been revived on being brought out into a warm atmosphere. In the warm-blooded animals that hibernate the torpidity is less deep than in those which are cold blooded. In them the respiration and the circulation become very slow, but never entirely cease. Indeed some species take food with them into their winter quarters, and occasionally wake up sufficiently to eat. But most of them are in a quiet, deep sleep, from which they do not arouse at all till the winter is past. In this state, as life is nearly, sometimes quite at a stand, there is no wear and tear, and therefore no change in the tissues, and so there is no need of the introduction of oxygen by the respiration. Dr. M. Hall, in his experiments and observations, found that the bat, when completely torpid, consumed no oxygen, and discharged no carbonic acid from the lungs, although its circulation was not entirely suspended.

159. The more active is the respiration of animals, the less able are they to bear a deprivation of air. A warm-blooded animal will die if it be under the water only a few minutes; but a cold-blooded animal can live under the water for some time, beeause it is not in so urgent need of oxygen. And, for the same reason, a warm-blooded animal, in a state of hibernation, may be kept under water for a long time without destroying life, although when in its active state it would die on being

kept under water for only a few minutes. And this suggests a probable explanation of those cases, in which individuals have been restored, after having been under the water longer than the usual time that suffices to destroy life in drowning. In such cases, the condition is not simply that of a drowned person. A blow, or the shock of body or mind, or both, may have induced a suspension of active vitality, like that which we see in the animal in a state of hybernation. The bare fact of immersion in the water may have but little or even nothing to do with the actual condition. Such a state of things is especially to be suspected in those cases in which the countenance does not exhibit the usual dark and full appearance of drowned persons.

160. I have thus shown the extensive play which the respiration has in the vital operations of the system. I have shown what the chemical changes are, which it effects directly in the lungs, and indirectly in the system. And you have seen how the animal heat is produced by these changes, and how unaccountably it is so regulated, that it seldom varies to any extent from its fixed standard. But it is to be remembered that, while the lungs, and even the capillaries, everywhere are thus chemical laboratories, the nervous system exerts a constant influence upon this chemistry of the body. This is especially seen in regard to the production of heat, but it is true of the whole range of the chemical operations. The laboratories would all cease their work if their nervous connections were destroyed.

CHAPTER VIII.

FORMATION AND REPAIR.

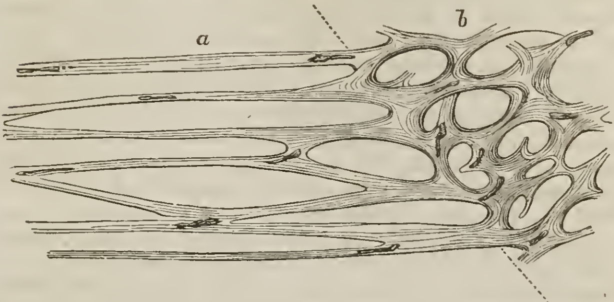
161. The building and the repairing of the various structures of the body are done by vessels appended to the capillaries. The capillaries having received from the arteries the blood, the building material, the formative vessels select from it, while it is in these capillaries, whatever they need for their purposes. The selection is made according to the tissue or structure to be formed. Those vessels which, for example, form bone, select from the blood very different constituents from those which make nerve or muscle.

162. It is wonderful that the blood can be formed from such a variety of food as is often taken into the stomach. But it is far more wonderful that from the blood can be made so many and such different structures. How different are the teeth from the gums which surround them; and yet both are made from the blood. Observe, in some particular part of the body, how many different structures there are which are all made from the same common material. Take, for example, those which are in and around the eye. There are, the skin of the eyelids; the eyelashes; the vascular lining on the inside of the lids; the cartilages of the lids; the firm, white coat of the eye, giving to the eyeball its firmness; the thin, transparent window in front, setting into the firm, white coat, like a watch-glass into the case; the beautiful iris, a round moving curtain with a central opening; the lens behind this opening; the optic nerve expanded on the inside of the cavity of the eye; the muscles that move the eye, with their tendons; the tear-gland; the cushion of fat on which the eye reposes; the bone which forms the socket, &c. All these various textures are formed from the blood; and the different workmen are as unerring in their selections from this common material, as if they were intelligent beings. Indeed, no ordinary intelligence could accomplish such a selection. It is effected, inscrutably to us, under the direction of an all-wise Intelligence, and by Almighty power.

163. But these builders of the body not only have the power of selecting their building materials from the blood, but they work in concert. Each company of builders work together in harmony, as if they were under intelligent leaders. And though different companies may be in close proximity, there is no disagreement nor interference. For example, the builders of a tooth and the builders of the gum around it, do not encroach on each other; but each do their appropriate work within their assigned limits. Even when different structures are intermingled, as when tendon and muscle mingle together at their place of union, there is no confusion in the work of the two sets of laborers. In Fig. 48 you see the difference in structure between the transparent cornea in the front part of the eye and the white coat, the sclerotic coat, into which the cornea is set like the crystal of a watch. It is represented as seen magnified 320 times. The dotted lines mark the place of union. The cornea, *a*, is a much more open structure, you observe, than the sclerotic coat, *b*. The builders of these two structures, though some of them are in such near neighborhood

Concert of action shown in producing different shapes.

FIG. 48.



never encroach on each other, but each set adheres strictly to its own kind of work. The sclerotica-makers never go to making the open work which you see in the cornea. If they should do so at any point there would be a little transparent window at that point in the white of the eye; and if the cornea-makers should at any point make close work like that in the sclerotica, there would be a white spot in the cornea.

164. The concert of action which we observe in the different sets of formative vessels is to be looked at in another point of view. It is such that they give a definite and peculiar shape to the structure which they make. Each bone differs in shape from every other bone, each muscle from every other muscle; and so of other parts. There is very great variety of shape in the structures of the body; and each shape can be determined only by a certain concert among the builders. That you may realize in some measure the extent of this variety, observe again the numerous different textures which I have mentioned as making up the eye. Each of these has its own peculiar shape, and its definite limits. Its builders work after a fixed plan, and within fixed bounds.

165. This concert of action may be looked at in still another point of view. If the different structures in the body were made, as a crystal is, by layer after layer of particles deposited upon the outside, wonderful as the concert among the little builders would be in that case, it would not be any thing like as wonderful as it is now. In the growth, that is the construction of any part, the addition is made by the formative vessels at every point of the part, and not upon the outside merely. As these builders are at work enlarging the part in the growth from infancy to childhood, they must so act in concert, as to

preserve the same general form in the part during all the successive stages of growth. And, as all the different structures of the body enlarge together, there must be agreement between different sets ; else there would be encroachment and confusion. Thus in the growth of the tiny arm of infancy to the sturdy arm of manhood, each set of builders must during all this time keep within its proper limits, so that there may be just the right proportion, and the right position of bone, and muscle, and tendon, and ligament, and cellular membrane, and skin, and nail, &c., that make up the arm.

166. But this concert of action appears the most wonderful when a new action, or change of action is called for. In the transition from childhood to youth, for example, the builders of the apparatus of the voice, the larynx, all at once become unusually active in their work, and a great enlargement of this musical instrument, for such it is, takes place, so that it may now utter the grave notes of manhood. Soon, too, the beard-builders begin their new work upon the face. And during the period of childhood new operations have been continually instituted among the builders of the teeth, as one tooth after another has made its appearance, and as the new set have replaced the old. To produce in the enlarging jaw a new set of teeth to take the place of the smaller and less numerous first set, and to bring them out in a symmetrical arrangement, require a very complicated series of operations. To effect each one of these, there must be concert of action among the formative vessels ; and there must be a most wonderful concert among the different sets and succession of builders, to make all these series of operations work out at length the general result.

167. This change of action in the formative vessels is strikingly exemplified in some animals. I refer to those that so entirely change their forms during the period of their existence. I will give two examples. The first is the common frog. He is at first what is termed a tadpole, and goes through many successive changes to become a complete frog. These changes are represented in the following figures. The relative sizes are not preserved, the tadpole state being represented relatively much too large, for the purpose of showing more clearly the development of the legs. The young tadpole is represented in Fig. 49. It has a large head and body, and a long flat tail by which it swims easily. There are no prominences to indicate the putting forth of any thing like limbs. It

FIG. 49.

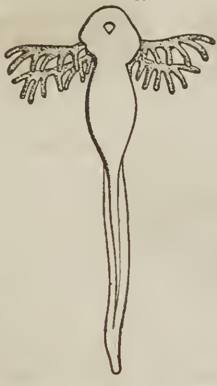


FIG. 50.

FIG. 51.

FIG. 52.

FIG. 53.

FIG. 54.

has gills, which are loose fringes on each side of the head. These gills after a time disappear, and it has another set of gills arranged under a fold of skin very much like the gills of a fish. The form is then as in Fig. 50. The next change is this. The hind legs begin to grow out as seen in Fig. 51. Next, the fore legs appear as seen in Fig. 52. The tail is still very large. This now gradually disappears while the legs grow as represented in Fig. 53. In Fig. 54, representing the perfect frog, the tail has entirely disappeared. With these exterior changes interior ones have been going on also. The animal, which was at the first a real fish, breathing with gills and swimming in water, has lost its gills, and has now a pair of lungs; and it is no longer able to remain long under water, without coming to the surface to breathe the air.

168. The other example is the silk-worm. It is represented in Fig. 55. When it has attained its full growth, it passes into what is termed its chrysalis state, Fig. 56, it having previously woven for itself from its silken thread a case or cocoon. While it is in this state of inactivity great changes are going on in its structure, and it at length becomes a perfect winged insect, as represented in Fig. 57.

In the two cases which I have described, in each successive change, the concert of action in the formative vessels is pre-

served, but it is after a new plan. This change of plan makes the concert of action exceedingly wonderful.

FIG. 55.

FIG. 56.

FIG. 57.

169. The change of action in the formative vessels, which is sometimes called for by accident and disease, exhibits in an interesting manner the concert between these vessels as influenced by circumstances. When a bone is broken, these formative vessels set themselves to work to repair the injury, by forming new bone between and around the two ends of bone, which new bone we call callus. In this case, the bone-builders extend their range of operations to meet the new necessity; and in doing so they maintain the same concert which marked their usual operations before the bone was broken. I stated in § 105, that when an artery is tied, to cure an aneurism, the circulation in the limb is kept up by the small arteries that go off from it above the ligature, communicating with those that branch off below; and that, in order to make the circulation perfect, some of these communicating arteries gradually enlarge, to meet the necessities of the case. Now, this enlargement is not a mere dilatation produced by the distending blood. The arteries grow in thickness as well as in capacity. The artery-builders are awakened to a new activity, and make the arteries in this quarter after a larger pattern than the one originally designed for them.

170. Concert of action under successive changes is strikingly exhibited in the processes of inflammation. The following account of these processes is from a work published by the author, entitled "Physician and Patient." "You see a swelling.

It after a while begins to soften. There is matter in it, but it is not yet very near the surface. But soon, at some point, it comes nearer and nearer to the surface, the wall of the abscess thus becoming constantly more thin, till, at length, it opens and discharges. The discharge continues till the swelling is nearly all gone, and the remainder is absorbed, and the part is restored to its natural state. Just look for a moment at the complicated character of this apparently simple operation. Here is quite a large deposition of substance which is to be removed; and this is the object to be effected. Observe how it is done. The softening of the swelling is not a mere change of solid substance into a fluid, as if by decay, but it is the result of an active process, which we call suppuration. When this process is properly performed good pus is made, or as the old writers in medicine rather quaintly expressed it, *laudable* pus. This process of suppuration, when it is well done, does not go on here and there in the swelling, making it like a honeycomb with a multitude of little abscesses; but there is a consent, an agreement of action by the vessels of the part, as really as if they worked intelligently. It is this consent of action which not only makes the line of movement in the abscess, but points it towards the surface, instead of giving it some other direction, laterally or inward, upon some of the internal organs. But it is further to be observed, that in this agreement of action, the vessels of the part do not all do one thing. Three different offices are performed by them in the different quarters of the abscess. While some of these little workmen are forming the pus, there are others thinning the wall of the abscess in the direction of the surface, by absorbing or taking up the substance there; while there are others still, in the rear, and at the sides of the abscess, depositing substance, in order to make a barrier to prevent the pus from being diffused in the surrounding parts. Each class of these workmen perform their particular work with even more exactness and harmony, than would be expected of any company of intelligent laborers under the direction of a leader. The absorbents absorb together, the wall-builders build together, and the makers of pus make pus together, and deposit it in a common reservoir.

171. But observe farther, and you will soon see an entire change come over the whole scene of operations. When the absorbents have completed their passage for the pus through the skin, the pus is gradually discharged from its reservoir, and

the "occupation" of the pus-makers is soon "gone." The wall builders also cease their work, and while the vacancy becomes filled up by contraction and deposition, the wall of defense, so carefully maintained so long as was needed, is now taken up by the absorbents, workmen which seem to know just when, as well as how, to do their duty."

172. Here you have concert of action exemplified in a complicated set of associated actions, to accomplish a temporary purpose. These actions, as you see, change in the different stages of the process, each one being performed just at the time, and during the period that it is wanted. And when the temporary purpose aimed at is accomplished, the vessels of the part resume at once their ordinary duties. It is to be observed also, that the concert of action is not confined to the formative vessels; but it appears also in those vessels called absorbents, of which I shall speak soon more particularly. And these two sets of vessels do not interfere with each other, but have a sort of agreement together in accomplishing the general result. This concert of action is plainly seen among the absorbents, not only in this case, but in all the cases that I have cited as exhibiting it among the formative vessels. For example, in the case of the frog (§ 167) while the formative vessels are constructing the legs, the absorbents are removing the tail. So in the case of the teeth (§ 166) while the formative vessels are constructing the second set, the absorbents remove the ends of the fangs of the teeth in the first set, so that they are loosened in their sockets, and are thus taken out of the way of the coming teeth. And indeed, wherever there is formation, there is absorption; and the same concert of action always appears.

173. I have spoken of the great variety of structures, which are made out of the same material, the blood. Besides this, all the different secretions are also formed from the same material. This appears wonderful when we look at the difference between such secretions as the tears, the ear-wax, the gastric juice, the bile, &c. And it appears more wonderful still, when we consider that these various glands, or factories, as we may call them, are built from the same material out of which they make their products. There is one curious exception to this. It is in the case of that large gland, the liver. This gland is built and kept in repair, like all the other glands, by arterial blood. But while they make their secretions out of this arterial blood, the liver makes its secretion out of *venous*

blood, which is brought to it for that purpose as described in § 108.

174. Thus, all the solids and fluids in the body are made from the blood. Even the heart itself is made from the blood which it pumps out into the aorta; for from this aorta go out some small arteries, to carry blood to the walls of the heart for its growth and repair. These arteries are represented in Fig. 31.

175. There is not only construction going on in every part of the system, but there is waste also. The wear and tear of the ever-moving machinery continually makes some of the particles useless, and these must in some way be removed. I propose now to show how this is done.

176. There are two kinds of waste particles; and for the disposal of them two different plans are pursued. Some of the waste particles, though wholly useless where they are, can be rendered fit to be used again by being subjected to certain processes. These, therefore, are not thrown out of the system, but are taken up by absorbents, and are carried where the necessary processes can be applied to them; and then they are introduced into the blood, to make again a part of the building material. But there are some waste particles that can not be used again; and these are so managed as to be got rid of at various outlets of the system. These two kinds of particles are taken up by two different sets of absorbents. The selecting power which they thus exert is as unerring as if they were possessed of intelligence; and it is wholly unaccountable, although some physiologists have attempted to explain it.

177. The particles which can be used again are taken up by absorbents, which are termed *lymphatics.* These vessels are much like the lacteals, the absorbents in the intestines. They unite together, as they come from all parts of the body, into two trunks. One of these is the thoracic duct (described in § 91), which is the common duct, both of the lymphatics and the lacteals, (Fig. 17,) and in which the chyle and the lymph, as the fluid in the lymphatics is called, are mingled together. The other trunk, which receives the lymph from but a small part of the body empties its contents into a large vein at the right side of the top of the chest. The largest part of the lymph, therefore, unites with the chyle, and is poured with it into the circulation, and the rest reaches the same destination by another way. It all becomes with the chyle a part of the blood. But before this is done it passes, like the chyle, through

glands, in order to fit it to become again a part of the building-material of the body. These glands are every where in the track of the lymphatics. They are often enlarged from disease, and then they can be readily felt. This is often the case with these glands in the neck. In relation to this appropriation of waste particles, which I have thus described, it may be truly said that man lives in part upon his own flesh.

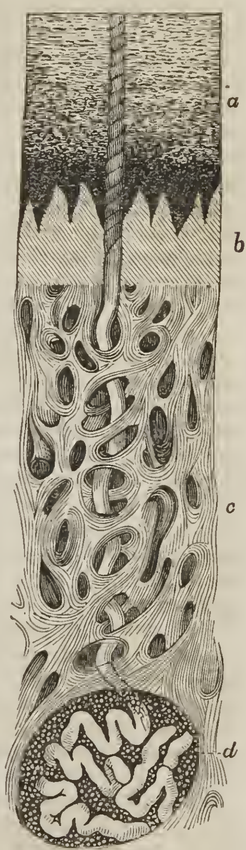
178. Those waste particles which are entirely useless are taken up by the veins directly into the circulation. They then travel the rounds with the blood, and are thrown off from the system by organs appropriated for that purpose. These organs are the lungs, the skin, the liver, the kidneys, &c. Each of these excretory organs is fitted to throw off its particular part of the waste. Thus the lungs, excrete a kind different from that which the skin does; and so of the rest. The lungs, as you saw in the chapter on respiration, throw off in the form of carbonic acid gas, large quantities of the carbon evolved in the wear and tear of the system. The liver, the skin, &c. throw off parts of the waste which differ from that which is thrown off by the lungs. Why it is that the waste matter is thus introduced into the circulation to be carried to the excretory organs, instead of having special channels appropriated to the particular office of carrying it to its outlets, we know not. And how it can thus be mixed with the blood, and be carried about the system without proving noxious, is a mystery. That it cannot be long retained in the blood without doing injury, is shown by the evil results, which come from a suspension of excretion from any of the organs that I have mentioned.

179. It is interesting to observe that some of the excretory organs perform other functions besides that of mere excretion.* Thus the lungs, while they excrete carbon, absorb oxygen, without which life could not go on. At the same time, too, they act as the bellows for the organ of the voice, the larynx, as you will see in the chapter on that subject. So also, the liver, while it excretes what would be noxious if it remained in the blood, puts its excretion into such a form, that it proves, as you saw in the chapter on digestion, an auxiliary in some of the processes of the digestive organs.

* The words *excretion* and *secretion*, are often applied to the same thing. Excretion, strictly speaking, should be applied only to something to be *thrown off*, and not to something formed to be used. But sometimes an excretion is so formed, that it can be used, and then the word secretion is also applicable to it. Thus the bile, while it is an excretion containing noxious particles to be thrown off from the system, is put to use, and so it is as often called a secretion as an excretion.

180. The skin, while it is an extensive excreting organ, performs other important offices. It serves as a firm yet very flexible and soft covering to the body, protecting its internal parts from injury. It is highly endowed with nerves for two purposes—the one, that it may act as a sentinel to warn of danger; and the other, that it may be the seat of the sense of touch. That you may see how well it is fitted to perform these various functions, I will describe here its structure. What is very commonly spoken of as the skin, is not really the skin, but only a covering for it. When the skin is rubbed off, as it is expressed, it is only this covering of the skin, or *cuticle*, which is removed. The skin which is raised by a blister is this cuticle. The great object of the cuticle is to protect the true skin, which is very highly endowed with nerves for the purposes mentioned above, and which therefore, if uncovered, would prove a source of severe suffering. As it is, the cuticle protects the skin effectually, and yet does not interfere with its functions as the organ of the sense of touch. It is of so slight and so soft a texture, that the nerves of touch may readily receive impressions through it. It is composed, as you will see in the next chapter, of many layers of minute round cells, the outermost layers being made up of these cells broken, and emptied of the fluid which they contained. The true skin, which the cuticle covers, is of a fibrous texture, with a good supply of both nerves and blood vessels. On the surface of this true skin next to the cuticle are eminences called papillæ. In these are seated the extremities of the nerves of touch. Fig. 58 represents a highly magnified section of a bit of the skin from

FIG. 58.

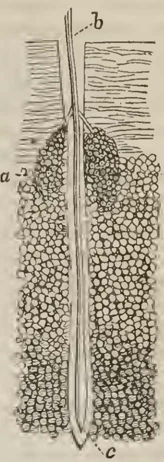


Vertical section of the
SOLE OF THE FOOT.

the sole of the foot; *a* is the cuticle; *c* is the true skin; *b* represents the papillæ. You observe that the deepest layers of the cuticle, next to these papillæ, are more colored than the outer ones. The coloring matter of the skin is situated here. You observe also a tube which runs up through the cutis or true skin and the cuticle, and in the latter part of it's course has a sort of cork-screw arrangement. This is the discharging tube of the sweat-gland, *d*, lying within the true skin, and surrounded with globules of fat. These glands are more numerous in some parts of the skin than in others. They are particularly numerous on the palms of the hands, and on the soles of the feet. Mr. E. Wilson counted, with the aid of the microscope, 3528 of them in a square inch on the palm of the hand. Reckoning the length of one of these at one quarter of an inch it gives 882 inches or 73½ feet of tubing in this small space. He calculated the amount of this tubing in the skin of the whole body as being 48,600 yards, or nearly 28 miles. The amount of excretion from the seven millions of these tubes, which open on the surface of the skin, is very great. Many experiments have been tried to determine what the amount is in 24 hours, but approximations only to the truth, of course, could be obtained, and the results of the experiments have differed much. While the excretion is great in amount, it is very important. It is, as you have seen in the chapter on Respiration, a great means of regulating the temperature of the body. It is also the means of discharging from the body a portion of its waste. This waste is dissolved in or mingled with the water or vapor of the perspiration. The perspiration is ordinarily *insensible*, as it is termed; that is, it is in the form of vapor. But sometimes, as in vigorous exercise, when the sweat glands are rendered very active, chiefly to prevent too great an accumulation of heat, the perspiration becomes *sensible*.

181. There is another set of glands in the skin called sebaceous glands, which secrete an oily fluid. They have also thin tubes like the sweat glands. They are most abundant where the skin specially needs an oily lubrication, as where there are folds in the skin or hairs, or where the skin is exposed to friction, or to the drying atmosphere. They are very abundant on the face and head. The amount of the oily secretion of these glands is very great in the skin of races fitted to inhabit warm climates. Every hair has sebaceous glands connected with it, as represented in Fig. 59; in which *b* is the hair emerging from the skin;

FIG. 59.



HAIR
and sebaceous glands.

a a are the sebaceous glands pouring their secretion by thin tubes into the tube or canal in which the hair grows; *c* the root of the hair surrounded with fat globules. From all this you see that the skin, with its two sets of glands and tubes, its nervous papillæ, and its layers of constantly renewed cells, making the cuticle, is a complicated organ, and is thus fitted to perform its functions as an organ of sensation, and at the same time of excretion, while it is also a pliable but firm covering for the body.

182. You have seen in the facts developed in this chapter, that there is constant change going on in all parts of the body. Particles which have become useless are taken up by the absorbents, while the formative vessels deposit others to take their places. The rapidity with which this change occurs, depends mostly upon the activity of the individual. The busy laborer, whether the labor be bodily or mental, requires more nourishment than the indolent man, because there is more waste in his case, from the wear and tear occasioned by motion or thought, and there is therefore a necessity for a larger supply of repairing material. The difference, it is true, is not as great in regard to mental labor, as in regard to that of the body; but still it is very apparent. This dependence of the amount of change in the system upon the degree of activity is very manifest, if we compare different animals together in this respect. I have already contrasted the frog and the canary bird in regard to respiration (§ 156,) and they can be contrasted in this respect also. As the frog makes but little exertion either of body or mind, there is but little change in his body, and but little nutriment is required to supply the small waste that occurs. But in the ever active canary there is much waste from this action, and therefore there must be much eating to supply the material of repair. As he sings and hops from perch to perch, his mind as well as his body is vastly more active than that of the frog; and so the particles in his brain and nerves, as well as in his muscles, are oftener changed. You see the same thing still more strikingly, if you contrast

the torpid state of the hibernating animal in winter, with his active state in the warm weather. In his torpid state life is dormant, almost at a stand still, sometimes entirely so. And the more perfect the quiescence, the less is the change, and the less, therefore, the need of nutrition. The fat which he lays up in the autumn (§ 65) answers all his necessities both for nutrition and for heat.

183. The proportion, thus seen to exist between the amount of change and the degree of activity, is exemplified in a comparison between different parts of the body. In those which are most actively used the change of decay and repair is going on most constantly. The active muscles and nerves are continually changing; while the bones, which are only passive instruments of motion are changed very slowly. And it is a significant fact, that in the case of the muscles and nerves, the waste particles are to a large extent of the entirely useless kind (§ 176), for they are mostly absorbed by the veins, there being in them but few lymphatics. That is, whenever we think, or feel, or move, we render entirely useless quantities of the particles which make up the structure of the muscular and nervous systems, and these are got rid of at the proper outlets, while other particles immediately take their places.

184. It is a very prevalent notion in the community, that the human body changes throughout once in every seven years. But you have seen that the change is very unequal in different parts of the body, and is dependent to a great extent on circumstances. Sometimes very rapid changes occur. Thus, when one has been much reduced by sickness, and then on recovery quickly regains his usual bulk, the body is very extensively changed in a short period of time. Ordinarily the circumstance which most influences the change is, as you have seen, the degree of activity which exists, whether we look at an animal as a whole, or at the tissues separately.

185. In this constant change going on in the body, life and death may be said to be brought into very near companionship. Every act of the mind, and every movement of the body breaks down some of the structure; and the particles, which are no longer fitted to maintain the living functions, must be taken away as refuse dead matter, and new particles endowed with vital affinities must take their place. Action, destruction, repair, are the successive events which are ever occurring in in every part of our frame. Action is followed by destruction, and in proportion to its intensity; and repair is necessary to

fit for further action. And so through life the nutritive functions are thus struggling against the tendency to decay and death, till at length at the appointed limit the struggle is given over, the vital affinities release their hold, the common laws of dead matter take possession of the body, and the soul passes to a world where decay and change are unknown.

CHAPTER V.

CELL-LIFE.

186. In previous chapters, in treating of the construction of the body, I have spoken of the formative vessels in accordance with the common language of physiologists. The common idea has been hitherto, that the work of construction is performed by vessels appended to the capillaries. The capillaries were considered as the repositories of the blood, they receiving it from the arteries, and holding it in readiness for the use to which it is to be put by the formative vessels. These formative vessels, it was supposed, exercised in some way a power of selection in regard to the constituents of the blood, and also a power of uniting the constituents thus chosen into particular forms. In this way physiologists accounted for the formation of all the different structures in the body. What shape these formative vessels had, or how they were arranged no one pretended to know. But of their existence no one had a doubt, for there seemed to be an absolute necessity for supposing some apparatus of vessels appended to the capillaries for the performance of this function.

187. But the microscope has of late years revealed phenomena which have changed our ideas on this subject, and which must to some extent change our modes of expression in relation to it also. It has showed us agencies which differ from those which we had supposed to exist. The subject is an interesting one, and I propose in this chapter to give you some glimpses of this interior life, as it may be termed, of the body.

188. It is found by the aid of the microscope, that all the minute operations of the system are performed by the agency of *cells*. They are not such cells as I described in § 64 as existing in the cellular tissue, which are mere interstices, communicating together. But they are bladders or sacs, and are

filled either with a fluid alone, or with a fluid containing some grains of solid substance, termed molecules. The usual form of the cell when it first appears is globular or spheroidal. It is seldom, however, seen in this form; for, besides the change of form from the pressure of neighboring cells, the cells themselves often change into various shapes, as you will see in another part of this chapter.

189. Cells can be seen in the blood. If the web of the foot of a live frog be placed under the microscope, you can see them sweeping along in the blood vessels, like so many little bladders, varying their shape, according as they press on each other, or on the sides of the vessel. This is very well represented in Fig. 60, in which a portion of the web of a frog's foot is seen as magnified 110 diameters. The dark irregular spots which you see, as at 3,3, are pigment cells, which give the color to the part.

FIG. 60.

CAPILLARIES IN THE WEB OF A FROG'S FOOT.

190. Cells may be seen in most of the fluids besides the blood, and also in the solids. The solid parts of animal bodies,

are composed either of cells, or of structures produced by cells, or of a mixture of these structures with cells. The same can be said also of plants. Cells, therefore, are the real formative vessels in both classes of organized beings.

191. We have very striking exhibitions of the cells in the lower orders of animals. The Hydra, a representation of which is given in Fig. 1, seems to be made up of little else than cells. If you observe under the microscope one of its arms, as it moves about, the motion appears to be a motion of the cells upon each other. There are no fibres to be seen, to which the motion can be attributed. Fig. 61 represents one of these arms highly magnified. The cells, as you see, have somewhat of a spiral arrangement.

FIG. 61.

CELLS

In the arm of the Hydra.

192. The character of many of the tissues in the body depends on the *contents* of the cells. The cell itself, or the cell-wall, as it is termed, is considered to be always the same. But the contents vary, and this variation makes generally the variation in the character, and in the color also, of the various textures. For example, all the glands are constructed essentially on the same plan; and their difference depends upon the contents of the cells in them. Thus the liver differs from the tear-gland, chiefly because the former has cells which fill themselves from the blood with the components of bile, while the other has cells which fill themselves with the components of the tears. The color of various parts, as the iris of the eye, the skin of the dark-colored, the hair, &c., depends upon a coloring matter, which constitutes either a part or the whole of the contents of particular cells. So in plants the various colors displayed result from the various coloring matters which certain cells contain. Some contain yellow coloring matter, others red, &c. When various colors appear together in any flower, there are, where the colors bound upon each other, cells lying side by side which contain different coloring matters. And in the shading off of the colors, the effect is produced wholly by the variation in the quantities of the coloring matter in the cells.

193. It is clear from the facts which have been stated, that the cells have a selecting power. In the body they take from the common pabulum or material, the blood, such constituents

or substances as they need for their particular purposes. I have already given illustrations of this, in speaking of the difference in the glands. This selecting power is seen in the cells everywhere. Every cell contains its own peculiar constituents, which it has taken from the blood. For example, there are fat-cells which receive fatty matter from the blood, rejecting every thing else; pigmentary cells receiving nothing but coloring matter from the blood, &c. The same thing appears too in plants. There are cells which receive from the sap volatile oil; others, fixed oil; others, starch; others, coloring matter, &c.

194. Fluids, and sometimes gases enter the cells continually. The pores through which they enter are not visible even through the microscope, but of course such pores must exist. Their entrance is controlled by the selecting power to which I have alluded.

195. This selecting absorption thus performed by cells, as revealed by the microscope, is one of the most wonderful and mysterious phenomena in the material world. There is here a power in these cells which is unaccountable. The selection is made by the little cell as unerringly, as if its pores were controlled by an intelligence residing there. It has been said that this selection is a mere result of affinity; that a certain affinity exists between the contents of the cell, or the cell itself, for the constituents which are absorbed. But if it be so, the mystery comes no nearer to being solved than before. For how are these affinities, so numerous and various, established, and what are the principles by which they are governed? In either case the wisdom and power of the Creator may be considered as making, in this minute interior life of all organized substances, some of their most wonderful manifestations.

196. There is not only a selecting power in the cell, but there is often a converting power, by which new compounds are formed from the constituents introduced into it. The cell in this case, though so small as to be seen only by a microscope of considerable power, is a real laboratory, effecting chemical changes in its contents. There can often be seen quite a brisk movement in the molecules in the cell while these changes are going on.

197. Some cells produce other cells. This is the sole office of some of them. In some cases new cells are made by a separation of a cell into two or more. A sort of hourglass contraction takes place at the middle, by an inflection or fold-

ing in of the inner cell-wall, for the cell has two walls. At the same time the cell becomes elongated. An entire separation into two cells is thus, after a little time, effected; and then each of these cells becomes two more, and so on. In other cases cells are formed within cells. When this takes place, the nucleus, that is an aggregation or mass* of solid matter in the cell, separates into two different parts, each of which has a cell formed around it.

198. Cells, as you have already seen, do not all perform the same office, but there are cells for a great variety of purposes. A consideration of these will develope to you still greater wonders in the cell-life, and show you in the most interesting manner how great the Creator is in the minute operations of nature, as well as in those which are large and obvious to the naked eye.

199. There are different kinds of cells in the blood. There are colored and colorless ones. The office of the colorless ones has not yet been satisfactorily determined. But we know more about the colored ones. These give the red color to the blood. They are not red when looked at singly, but are of a yellow cast; and the red color appears only when several are together. One office of these colored cells is to carry oxygen to all parts of the system, and return the carbonic acid to the lungs to be thrown off. By carrying these cargoes back and forth in the circulation, these little cells perform a very important office. A very valuable part of the cargo of these cells is iron. In low states of the system, when the red cells are deficient, the administration of iron in some form is often found to be very effectual, in connection with a good diet, in remedying the deficiency. The proportion of these red cells varies much in different animals. It is largest in those which are the most active, and which, therefore, as you saw in the chapter on Respiration, consume the largest quantity of oxygen. The proportion is greater generally in birds than in the mammalia, and it is much greater in the latter than in reptiles or fishes. In man it varies much in different individuals. These cells are abundant in the ruddy, strong, and active; while it is otherwise in the inactive, pale, and feeble.

200. There are cells for absorption, and cells for secretion

* To the common ear the word *mass*, which is ordinarily used in relation to aggregates of some size, seems out of place when applied to a collection of molecules which is so small, that it can only be seen by a microscope of high power; but though so small, it is to the little cell containing it a mass.

and excretion. Of these I will give some examples. I have said in the chapter on Digestion, that the vessels called lacteals absorb chyle from the contents of the intestine. It was formerly supposed that they did this through their open mouths on the surface of the mucous membrane. But the microscope has shown that this is not so. The absorption is accomplished by cells, which are developed for this purpose at the extremities of the lacteals. They take up the chyle and discharge it into the lacteals, and they are dissolved away in the very act of emptying themselves. A new crop therefore of cells appears every time the process of absorption is to be performed. And, what is still more curious, every time that absorption is to take place, there is cast off, as a preparatory step, a sort of pavement of cells from over every point in the mucous membrane where there is an extremity of a lacteal. The absorbing cells are thus uncovered, so that they can perform their duty. All this can be made clear by the following diagram. I must premise that the surface of the mucous membrane of the intestine is not a perfectly smooth surface, but examined by a microscope it is seen to be covered with eminences and depressions. Absorption takes place on the eminences, while the depressions are the seats of secretion. In the diagram, Fig. 62, you have a

FIG. 62.

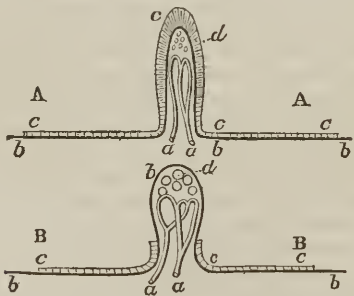


DIAGRAM SHOWING ABSORPTION IN A MUCOUS MEMBRANE.

representation of the arrangement of one of the eminences highly magnified. A, represents it as it is in the intervals of digestion when absorption is not going on, and B as it is during absorption ; *a a* are the absorbent vessels or lacteals ; *b b* basement membrane, as it is termed, an exceedingly thin membrane acting as a basement to the pavement cells *c c* ; *d d*,

the absorbing cells. When absorption is not going on, the prominence is somewhat shrunken, and the pavement cells cover it. There are some granules or small grains, *d*, in A, which are, it is supposed, the germs of the absorbing cells, which you see developed in B. When absorption is taking place, the prominence is swelled out as represented, the lacteal vessels are full, and the absorbing cells appear at their extremities, while the pavement cells have been thrown off, so that the chyle may have free access to the absorbing cells through the pores or interstices of the basement membrane.

201. While absorption thus goes on in the eminences, secretion takes place in the depressions. The diagram, Fig. 63,

FIG. 63.

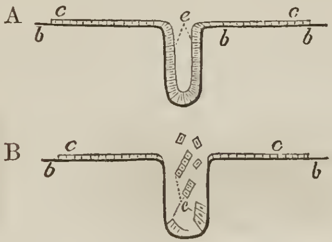


DIAGRAM SHOWING SECRETION IN A MUCOUS MEMBRANE.

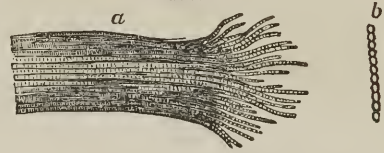
represents one of these depressions, or follicles, as they are termed, in two opposite states, when secreting, and when not secreting. In A, secretion is not going on, and the cells *e*, in the follicle remain quiet. In B, on the other hand, secretion is taking place, and it is done by the casting off of cells, as represented. These cells discharge their fluid contents into the cavity of the intestine, and disappear, while other cells take their places. These follicles are really little glands. And the various glands, the salivary glands, the liver, the pancreas, &c., are made up essentially of such follicles arranged in different ways. You see, therefore, in this diagram, the manner in which secretion is effected everywhere. The secreted matter is received by the absorbing cells, through the interstices of the basement membrane, from the blood in the capillaries which lie under this membrane.

202. The pavement cells, of which I have spoken, cover every part of the mucous coat or membrane, and answer as a protection to it. There is a similar arrangement over the whole outer surface of the body. Next to the true skin is a

basement membrane, and upon these, as in the case of the mucous coat of the alimentary canal, lie pavement cells. These cells, constituting the cuticle or scarf-skin, are much more numerous than in the alimentary canal. There are many layers of them. The outer cells dry by exposure to the air, and become scales. As these are rubbed off, the cells below take their places; and there is a constant supply of fresh cells from the basement membrane.

203. There are some cells which are devoted entirely to the production of motion, for an ordinary muscle is composed of great numbers of chains of cells included in sheaths bound together. A muscle appears to the naked eye to be made up of fibres. Each one of these fibres is found by the miscroscope to be composed of from 500 to 800 *fibrillæ*, or minute fibres. And each of these fibrillæ is a series or chain of cells. In Fig. 64, *a*, is represented a fibre as seen under the microscope,

FIG. 64.



FIBRE OF A MUSCLE.

showing the fibrillæ of which it is composed. They are separated at the broken end by the violence in tearing the fibre. In *b*, you see one of the fibrillæ very highly magnified, showing that it is a chain of cells. In the diagram, Fig. 65, is represented the condition of a fibrilla in the two states of contraction and relaxation. In *a* it is relaxed. In *b* it is contracted, the cells being shortened, and at the same time widened. And as all the cells in the muscle are thus widened when the muscle contracts, we see the cause of the well known swelling out of muscles when they are in action. That you may form some idea of the size of these cells in muscles, I will state that in the space of the square of a tenth part of an inch, thus, □ there are over 100,000 of these cells. When

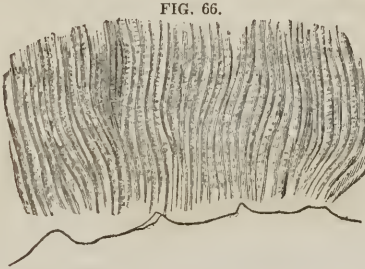
FIG. 65.

MUSCULAR FIBRIL; *a* relaxed; *b* contracted.

a large muscle contracts what an innumerable multitude of these cells are set in action !

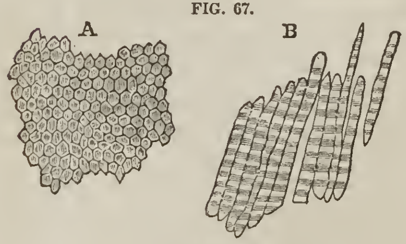
204. There are cells whose office it is to make certain solid deposits. Hoofs, horns, nails, and teeth are made in this way. Even the hard enamel of the teeth is constructed by cells. They deposit it in the form of prisms of hexagonal shape as seen in Fig. 66, which represents a vertical section of enamel as seen under the microscope. Their shape is more plainly seen in A, Fig. 67, which represents a transverse section of enamel. The line of these prisms is generally wavy, but they are for the most part parallel to each other. At B are some of these prisms separated. They are more magnified here than in Fig. 66.

FIG. 66.



VERTICAL SECTION OF ENAMEL.

FIG. 67.



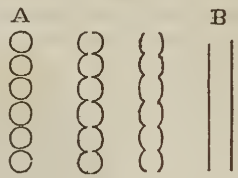
ENAMEL.

A, Transverse section. B, Separated prisms of it.

205. Perhaps the most wonderful exhibitions of the functions of the cell are presented to us in the nervous system. The nerves are bundles of tubes of exceeding fineness. They vary from $\frac{1}{1600}$th to $\frac{1}{10,000}$th of an inch in diameter. Now, each of these little tubes, or tubuli, as they are called, was once a chain of cells. The cells in each chain or row, as the micros-

cope has shown, gradually became incorporated together to become a tube, and in this tube is contained the true nervous matter. And it is supposed that each of these tubuli preserves itself separate and distinct, from its origin in the brain, or some other of the central organs of the nervous system, to its termination in some fibre, or on some surface. For no communications between the tubuli have ever been found by any microscopist. The manner in which these tubuli are made from cells may be illustrated by the diagram in Fig. 68, in which the steps by which the row of cells A becomes the tube B are represented.

FIG. 68.



206. It is these tubuli, thus formed from cells, that constitute the means of nervous communication between all parts of the system. Thus, when a muscle contracts in obedience to the will, an impression is conveyed through those tubuli that connect the brain with the fibres of the muscle, or rather with the cells of which these fibres are composed. These tubuli exist in all the nerves, and in the white parts of the brain and spinal marrow. They transmit, but they have nothing to do with originating what is transmitted. This is done by another part of the nervous system, the reddish gray substance, which is seen in the brain and spinal marrow, as entirely distinct from the white portion. This gray substance, in which all nerve force, as it is termed, is produced, is made up chiefly of cells. These cells, which have a nucleus or central particle, are originally globular, but many of them assume various shapes, and often shoot out branches. Some of the shapes are very fantastic as represented in Fig. 69. These are magnified 200 diameters.

207. In the views which I have given of cell-life, I have not attempted to describe all the phenomena which have been discovered, but only enough of them to give the student a general view of this interior unseen life, that is at work so busily at every point of every living substance. The cell, you have seen, performs a great variety of functions. It is the agent by which all vital operations are carried on. The very beginning of life, so far as we can see, is in the cell which the microscope reveals to us. Its first manifestation is here. We can suppose a germ as the origin of a cell, but we do not see it if it exist.

208. All animated nature is built up by cells. The first

FIG. 69.

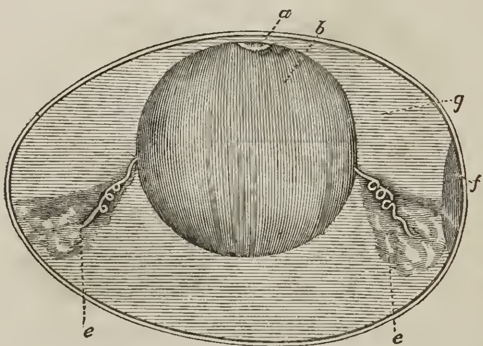
NERVE CELLS IN THE GRAY SUBSTANCE.

thing which comes from the supposed germ is a cell. And this single cell is the parent of all the cells which build up the whole structure, whatever it be. It is by these cells thus produced, that all plants and animals are constructed. "A globular mass," says Carpenter, "containing a large number of cells is formed before any diversity of parts shows itself; and it is by the subsequent development, from this mass, of different sets of cells, of which some are changed into cartilage, others into nerve, others into muscle, others into vessels, and so on, that the several parts of the body are ultimately formed. Of the cause of these transformations, and of the regularity with which they take place in the different parts, according to the type or plan upon which the animal is constructed, we are entirely in the dark; and we may probably never know much more than we do at present."

209. A beautiful exemplification of what has just been stated is seen in the development of the animal in the interior of an egg, and particularly in the egg of the bird tribe. By an ex-

amination of different eggs at different stages of the process of hatching, the various steps in the development of the animal have been observed and noted. It is a series of most wonderful processes, that go on concealed from our view by that symmetrical inclosure of lime. Of these I will present the general outlines. In the middle of the egg is the yellow yolk, composed of albumen and oil globules. It is surrounded by an exceedingly thin sac, which keeps it separate from the albumen, the *white* of the egg that envelopes it. The *yolk*, *b*, Fig. 70, is

FIG. 70.

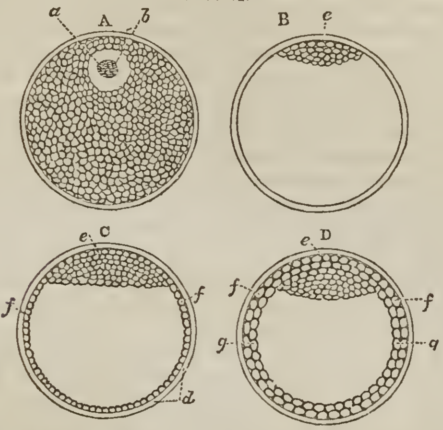


SECTION OF A BIRDS' EGG.

lighter than the *white*, and it therefore always seeks the highest point in the egg. But there is a particular contrivance which prevents it from actually touching the shell. It is held down by two very delicate ligaments *e*,*e*, connecting it with the white lining of the shell. And you will observe, too, that the cicatricula, or germ-spot, *a*, which is a collection of cells beginning the process which is to form the animal, being lighter than the yolk is always at the top of it, in order to receive the warmth from the body of the bird as it sets upon its eggs. Besides all this, there is at the blunt end of the egg, *f*, a bubble of air which is intended as an invigorating draught for the lungs of the young bird, preparatory to its bursting its shell.

210. When the processes preparatory to the formation of the animal commence, the yolk itself is composed in part of cells, as represented in Fig. 71, A. In the midst of it there is a germinal spot, *a*, with a vesicle in it, *b*. This vesicle produces

FIG. 71.



DEVELOPMENT OF CELLS IN THE YOLK DURING INCUBATION.

a cluster of cells. But these cells, and those which in part compose the yolk are temporary, and all disappear. Before, however, the cluster of cells in the germinal spot disappear, there are seen in the midst of them two twin cells. These multiply; and what is singular, they do it by doubling, so that there are successively 4, 8, 16, 32, &c. At length there is a mass of them, like a mulberry, as at *e*, in B. This mass then sends off cells at its edges which makes a layer, *f*, all round the yolk as represented in C. A second layer, *g*, is formed inside of the first as seen in D. In the case of the higher animals a third layer is added.

211. There is no formation of the animal yet. But now a single large cell appears in the centre of the mulberry-shaped mass of cells, and from this begins the formation of the animal. All the other parts of the egg—the cells, the yolk, the white—are tributary to the action which proceeds from this cell. Within its wall is a ring-like nucleus. This takes the shape of a pear, and then it is afterward very much like a violin. From this nucleus are produced cells which form all the various parts of the animal, the heart, lungs, stomach, brain, limbs, &c. And these are made out of the yolk and the white of the egg.

212. There is one contrivance made use of during this development of the animal, which must not pass unnoticed. A very delicate bag, called the *allantois*, is formed, which is attached to the embryo, and at length almost envelopes it. The office of this is to expose the blood of the embryo to the air. This is accomplished through the pores of the shell, against which the allantois with its minute blood-vessels presses. This organ is in fact the temporary breathing apparatus of the developing animal. The development can be arrested by smearing over the egg with some substance that will prevent the entrance of air through the shell. When the animal is fully developed, and is ready to come forth from his prison, he inhales the air provided for him, as before described, and with the strength given to him by the stimulus of the air in his lungs, he bursts the crust of lime that incloses him.

213. I have described these processes which take place in the egg, in order that you may see the mysterious connection between the simple cells that form in the beginning, and the full development of the complete and diversified organization. In the formation of all animals, and we may say plants also, there is a similar connection, varied of course according to the circumstances of each case. As we observe the various steps of the process, the mind is filled with wonder. As we look at the egg, containing nothing but a yolk surrounded by albumen, with its little cell of air at the end, and see it wholly separated from every living organization, shut up entirely by itself in a wall of lime, we can hardly believe that the mere application of heat will cause in the contents a series of processes, which will result in an animal so complete, that it can burst its own prison walls, and, as is the case with some of the tribe, at once walk forth into the open air. The processes by which all this is effected have been narrowly watched by the eager eye of scientific inquiry; but the mystery remains unsolved, and probably to man it will always remain so.

214. From the views which I have presented in this chapter it is manifest, that the grand distinction between organized and unorganized substances is to be found in this cell-life of the organized. In unorganized substances particles or molecules are the only things which we know of as being concerned in their formation. But in the construction of organized substances or beings, every thing is done by the agency of cells. And in this cell-life of the living world we have another beautiful example of the divers and almost numberless results, which

the Creator works out by simple and single means. As gravitation holds atoms together in masses of every size from the minutest to the largest, and keeps the mighty orbs in their appointed circuits, so the cell-organization constructs and moves all living things, however small, however large, and however diversified.

215. As we examine the various workings of this cell-life, we can not but perceive the truth of the old adage, *Natura in minimis maxima est*—nature is greatest in its smallest things. The power of mere bulk or mere force we can comprehend by mental addition, however great that power may be. We can imagine a power which we see, to be indefinitely multiplied, and thus can form the idea of immense power. But when with the microscope we see minute cells working out such results as we have contemplated in this chapter, and inquire how it is done, we see that there is a hidden power here that utterly defies our conception. The mechanics and the chemistry of the cell, who can understand them ? From the inscrutable movements of this hidden power, at work wherever life is, in the cells, its laboratories, we get a higher idea of Omnipotence than we can get from the grandest and most terrific exhibitions of mere force. We get from them the idea of an all-pervading, as well as an all-wise power, working not merely in every locality, but at every point of the universe. And the revelations which the microscope makes to us seem to draw us very near to the Infinite. As we gaze with wonder and delight at the secret operations of his power thus opened to us, we seem almost to be admitted to his presence ; and even our awakened curiosity, amid the wonders now brought into our field of vision, does not suffice to remove the awe which almost oppresses us.

216. How great is the inner beauty of the living world around us ! We admire the symmetrical forms, and the beautiful colors which nature presents to us in such variety ; but there is an inner world of beauties throughout nature, still more perfect and resplendent, which is hidden from the naked eye of man, though it is all open to the Omniscient. If you would get some idea of the beauty of this inner world, take the most delicately beautiful of all the specimens of man's workmanship, and examine it with a microscope ; and then compare it with some living texture or coloring. Compare in this way, for example, the most perfect painting of a flower with the flower itself. The painting loses all its beauty as it is magnified ; but in the bosom of the flower the microscope developes to you

beauties far transcending those which are seen by the unassisted eye. Even such living structures as are unattractive to the naked eye, present under the microscope wonderful beauty in the delicate lines of their textures. It is true of every one who has used this instrument in his observation of nature, that he is impressed with the fact, that great as is the beauty of nature, as we look out upon it, it is vastly inferior both in kind and in amount to that inner beauty seen so completely by the all-seeing Eye, and now developed to us in part by the skill and ingenuity of man. And it suggests to us the hope, that in a new state of being, and with higher faculties, we shall be able to look farther into these inner beauties of the universe, than we now can with all the aids which our ingenuity can devise.

PART THIRD,

CONTAINING

CHAPTER X.

THE NERVOUS SYSTEM.

217. THUS far we have contemplated man merely as a structure. We have observed the means by which the body is built and is kept in repair. We have seen that in regard to these functions of nutrition, man and all animals have much in common with plants. So far as these functions are concerned, they vary from plants only in the modes by which the nutrition is effected. The difference in this respect is not an essential one. The absorbents in the root of the plant do for the plant what the lacteals in the digestive organs do for the animal, the difference between them being only according to the differing circumstances. So also, circulation and formation are in all essential points the same in these two different departments of animated nature. The microscope has in the most striking manner shown this to be true of formation, for vegetables and animals are alike constructed, as you have seen, by cells.

218. The functions of which I have treated in the previous chapters, as being common to plants and animals, are called the functions of *organic* life, because they concern merely the structure, the *organization*. But there are other functions. The body, with all its complicated parts, is constructed and kept in repair for certain *uses*. These uses are secured by the nervous system,—a system, which I have spoken of in § 32, as being superadded to what the animal has in common with the plant, and which, therefore, constitutes the essential difference between the animal and the plant. This system furnishes the means of the relations of the animal to the world around him. He receives his impressions from external things through this

system; and through it he acts upon external things. He feels through the nerves, and by the nerves excites those motions by which he acts on both material and immaterial existences. The functions, therefore, which are performed through this system, are called functions of *animal* life, in distinction from the functions of *organic* life, which are common to vegetables and animals. They are sometimes also called functions of relation, in view of the relations which it establishes between sentient and moving beings, and all external things.

219. But there are intermediate instruments, through which the nervous system exercises its functions. The nerves do not themselves move, but they excite motion in muscles, and these move bones and other parts. Neither is sensation performed by the nerves alone. The different senses, for example, have different organs, with arrangements differing according to the kind of sensation. Mere nerves do not alone see, or hear, or taste, or smell, or touch. There are special organs constructed for these purposes; and through these the nerves receive impressions. Thus the nerve of sight cannot of itself see; but the eye being there, so formed as to have pictured on a membrane the images of objects, the nerve receives an impression from these images, and this impression is transmitted through the trunk of the nerve to the brain, where the mind takes cognizance of it; and this constitutes seeing.

220. While then the nervous system is the great essential means of connection between the mind and external things, there are other subordinate means, as we may consider them. They are organs of various kinds, through which the nerves act and are acted upon. The nervous system, therefore, may be viewed as presiding over the sentient and moving machinery, in the complex structure of the human system, which we have been examining in the previous chapters.

221. The nervous system in the lower orders of animals is very simple, and forms an exceedingly small part of the animal. But, as we rise in the scale, we find that, as the limits of relation to external things enlarge, this system becomes more prominent; till, in man, in whom these relations, both mental and physical, are much more extensive than in any other animal, it is very prominent and greatly complicated.

222. The interest of the class of subjects, now to be opened to you, much transcends that of the subjects which we have already gone over. If you look at a child as it first opens its

eyes upon this world, you see a being, whose senses are commencing their work as inlets of knowledge to the soul within. Nothing is known at the outset, of shapes, or colors, or distances, or any other relations of things. This is all to be learned, through the nerves and their subordinate organs. And as all knowledge is acquired through the nerves, so it is communicated through nerves to others. It is communicated by the motions that are excited in the muscles by the nerves—the motions of the countenance varying its expression; the motions of the limbs, or gestures; but especially by the motions which produce and articulate the voice. Thought and feeling can be communicated in no other way than by muscular motion.

223. From what has now been said, you readily see, what will be the subjects of the third part of this book. They are those which relate to the nervous system and its connections or dependencies. They are, the nervous system itself; the organs of locomotion, the muscles, and the bones; the voice; the expression of the countenance, and the language of the muscles generally; the senses, with their organs; instinct; thought; reason.

224. As preparatory to a particular view of these subjects, I will give you a general view of the nervous system, with the functions performed by the various parts of it. I shall reserve for another chapter a particular view of some of the higher functions of this system, and a consideration of some subjects, which we can better examine after we have considered the organs of locomotion and the senses.

225. The nervous system may be considered as having three parts; 1, certain central parts, as the brain and spinal marrow; 2, nervous trunks, which going from these central parts divide and subdivide, as the arteries do, till they become exceedingly minute; and 3, the nervous expansion in the organs, having a relation to the nervous trunks similar to that which the capillaries bear to the arteries. In what we call sensation we suppose that an impression is produced in the nervous expansion, that the trunk serves to transmit it, and that through the nervous centre, the brain, it is communicated to the mind.

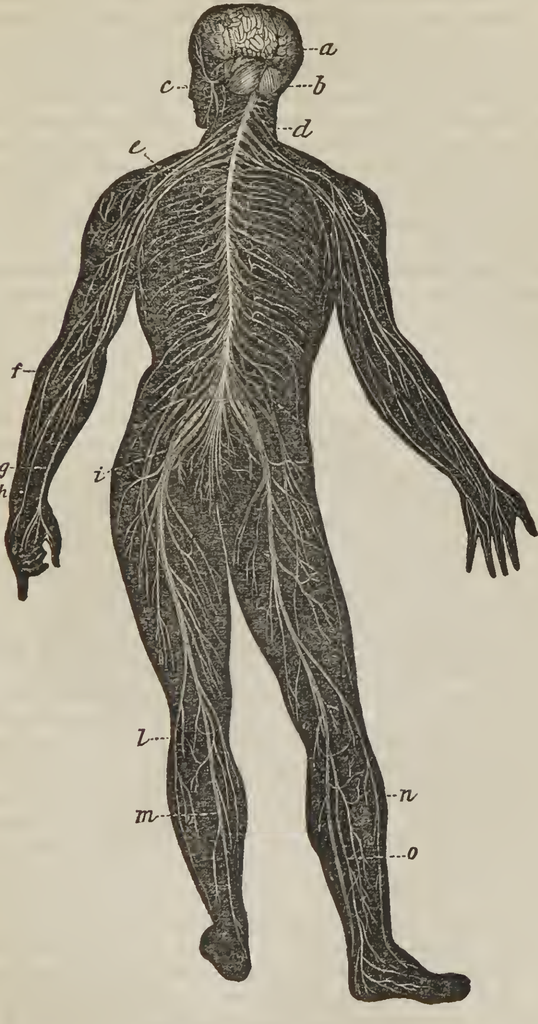
226. Let us see now what is necessary to this compound act, termed sensation. First, it is necessary that the organ where the nerve is expanded be in a condition to let the nerve receive the impression. If the eye be so injured in its textures, that the impression can not be made on the nerve, there can be no

vision. So, too, of the other senses. Taste and smell are often impaired, sometimes even destroyed for a time, by an inflammation of the mucous membrane, on which the nerves devoted to these senses are expanded. This is sometimes the case in a common cold. It is necessary also, that the trunk of the nerve be in a proper condition. If the nerve of vision be pressed upon by a tumor, there will be no impression transmitted from the images formed in the eye. So, too, if a nerve going to any part of the body be cut off, there can be no transmission of impressions to the brain from that part. Again, it is necessary to sensation, that the brain should be in a state to communicate the impression to the mind. If the brain be pressed upon strongly by a depression of the skull from violence, or by effusion of blood by the rupture of an artery, as sometimes occurs in apoplexy, there can be no sensation. Excitement of mind, too, sometimes prevents the occurrence of sensation, by its action upon the connection between the mind and the brain. The pain of a wound received in battle is often unfelt, until the excitement of the battle is over. The aching of a tooth is often stopped by the excitement consequent upon going to the dentist to have it extracted. I once burned my hand in the beginning of a chemical lecture, but felt no pain till I had finished it, and then the pain was at once very severe. In these cases the cause of the pain is acting all the while upon the nervous extremity, and the trunk of the nerve is capable of transmitting the impression, but the state of the mind is such, and such is the consequent condition of the brain, that the sensation does not occur—one link in the necessary chain is defective.

227. The same can be said, in regard to the necessity of each of these links of the chain, in relation to voluntary motion, as well as sensation. The brain must be in a condition to be acted upon by the mind; the nervous trunk must be capable of transmitting the impression; and the muscle must be in such a state, and in such connection with the extreme nervous fibres, that it can respond to the call of the brain.

228. Before going further, I will give you some idea of the proportions and arrangement of the central organs of the nervous system. In Fig. 72 you have presented a general view of this system,—the central organs with the nerves going out from them. At *a* is the cerebrum, the upper large brain, filling up a considerable portion of the skull; at *b* is the cerebellum, the lesser brain, lying beneath the cerebrum at its

FIG. 72.

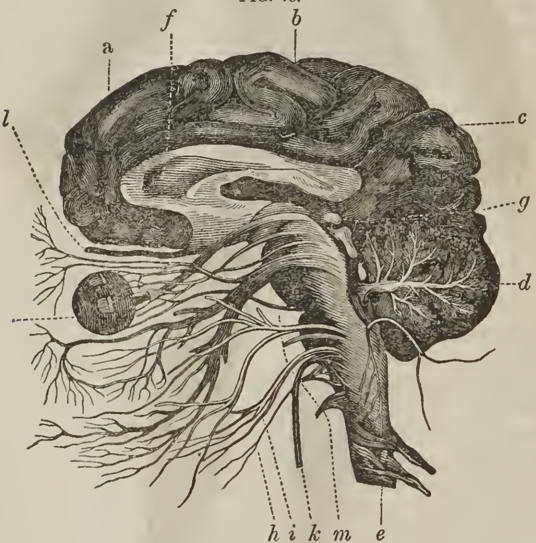


NERVOUS TRUNKS IN MAN.

back part: at *c* is the great facial nerve, the chief nerve of the face; the spinal marrow, *d*, sends off branches on either side in its whole length; at *e* is the brachial plexus, a bundle of nerves coming from the spinal marrow, which here unite together, and are then distributed to all parts of the arm; at *i* is a similar plexus from which are distributed nerves to the lower extremity; *f*, *g*, and *h* point to different nerves in the arm, and *l*, *m*, *n*, and *o* to different nerves in the leg. You observe that the whole of this nervous system is divided into exactly similar halves. The cerebrum and the cerebellum are both double organs, and the nerves of one side are just like those of the other.

229. Having thus observed the general arrangement of the nervous system, I call your attention next to the arrangement and structure of the brain which are seen in Fig. 73. This

FIG. 73.



BRAIN AND NERVES.

Figure presents to view a perpendicular section of the brain, as made from front to rear, dividing it into two halves. You have here a view of the inner surface of one hemisphere, as it is

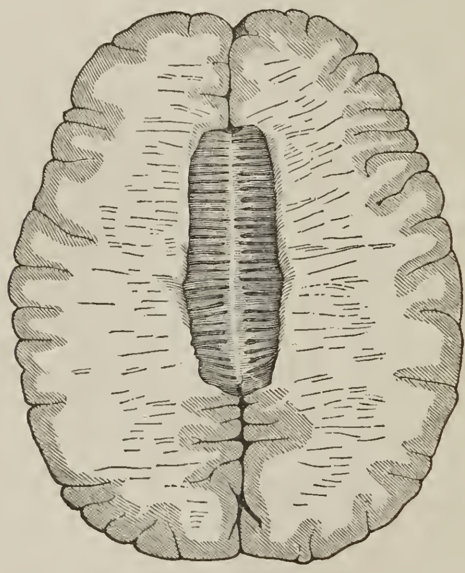
termed, of the cerebrum, the large upper brain, which is commonly described as having three lobes or divisions, *a*, the anterior; *b*, the middle; and *c* the posterior. At *f* is the broad band of white fibrous matter, which unites the two halves or hemispheres together, of course divided in the section; at *d* is the cerebellum showing a peculiarly beautiful arrangement, called the *arbor vitæ*, or tree of life; at *g* is the beginning of the optic nerve which goes to the eye; *l* is the nerve of smell; *e* is the commencement of the spinal marrow. The many nerves which you see, are distributed to various parts of the face; the nerve at *h* goes to the tongue; at *i* to the throat, and at *m* to one of the muscles of the eye. From the beginning of the spinal marrow go forth many nerves, one of which, *k*, is a very important one, as it sends off branches to the lungs, the heart, and the stomach. It is this part of the nervous system, the top of the spinal cord, that it is most immediately essential to the continuance of life. For it is by their nervous connections with the top of the spinal marrow, that the heart and lungs continue to perform their duty. It has been ascertained, by experiments upon animals, that the cerebrum, and even the cerebellum, can be destroyed, and yet the animal will continue to breathe, and the circulation will go on for some time. But the moment that this part of the spinal cord, from which the heart and lungs are supplied with nerves, is destroyed, the breathing and the circulation stop and the animal dies. So, too, in apoplexy, if the effusion of blood take place at the top of the spinal marrow, death will occur more certainly, and in much shorter time, than if the effusion take place in the cerebrum or cerebellum.

230. You observe that the cerebrum has deep irregular furrows on its surface, and that it presents undulating tortuous projections. These are called the *convolutions* of the brain. Into the furrows between them dips down the membrane, in which branch out the arteries that supply the brain with blood, and the veins that return it from this organ. This membrane is from its soft and delicate texture, called the *pia mater* (pious mother), while the stout fibrous membrane, which lies outside of this next to the bony covering is called the *dura mater*, or hard mother. The names are entirely inappropriate, for the latter serves as a protection to the brain, and the former is merely a vehicle or medium for the entrance of the blood vessels into the brain. There is another membrane lying between these which is called the *arachnoid* membrane, be-

cause in its tenuity and delicacy it resembles the spider's web. It is one of the serous membranes, and it serves as a protecting envelope to the brain, and at the same time by its serum, keeps this organ bedewed with moisture over its whole surface.

231. The substance of which the brain is composed is very soft, something like blanc-mange. It is the softest organ in the body. It is not uniform throughout in color. All around the white inner part of the brain there is a thick layer of gray substance. In Fig. 74 you have a horizontal section of the

FIG. 74.



SECTION OF THE BRAIN.

brain, showing the proportions and arrangement of the gray and the white substances. As the gray substance dips down, as you see in the figure, into all the furrows, its extent is greater than you would suppose at the first view. In the middle is represented the broad connection which exists between the two hemispheres of the brain. You observe in

Fig. 73, and Fig. 74, that there is no apparent arrangement of the external parts of the brain, which would give countenance to the idea of the phrenologist, in relation to a division into particular organs. The convolutions, so far from presenting any well defined arrangement, are exceedingly irregular.

232. The gray substance, which is sometimes called the cortical (bark-like) substance, because it surrounds the white central part of the brain, is made up, as I said in the Chapter on Cell-Life, § 208, of cells, while the white part is composed of exceedingly minute tubes. These tubes are continued into the nerves, and as they hold the nervous matter, they constitute the medium of communication between the brain and all parts of the body. This function of communication is the sole function of the white nervous matter. In the brain this white matter is a mere collection of tubes, and these branching out in bundles form the nerves. These tubes are supposed to be entirely separate from each other, from their beginning in the brain to their termination in the various parts of the body, for the microscope, as stated in § 205, has never discovered any union between them at any point. The brain then is a great central organ of communication, where innumerable minute tubes are brought together, each of which is connected with some one moving fibre, or some one sensitive point in the body. Those which are connected with muscular fibres transmit impressions *from* the brain, and those which are connected with sensitive points transmit impressions *to* it. Of the size of these tubes you can judge by Fig. 75, which shows some of them as they appear magnified 350 diameters. They vary much in size, but the cause of this variation has not been discovered.

FIG. 75.

NERVOUS TUBULI,
Magnified 350 diameters.

233. The office of the gray substance, it is quite well ascertained, is very different from that of the white substance, as the difference in its structure would lead us to suppose. It is more nearly

connected with the mind than the white substance. When, for example, motion is produced in obedience to the will, the impression producing the motion is transmitted through the white matter, but the cause of this impression does not act directly on this matter. The impression is caused by the action of the mind on the gray matter, and the white substance only serves to transmit it. The gray matter, therefore, has a more active agency than the white in the phenomena of the mind and the nervous system. It is the first link in the chain of connection between the spiritual and the physical in our nature. Hence, in examining the brains of animals, we find that the higher is the intelligence, the more abundant is the gray substance; and it is especially abundant in man, by the large development of the convolutions.

234. The question arises here, whether, as in motion the active agency is on the part of the gray matter in the brain, there is also gray matter at the extremities of the nerves of sensation, exerting an active agency there. It would seem that it should be so. When voluntary motion is produced, the action of the mind is on the gray substance, and the white substance of the brain and the nerves transmits the impression of this action. But in sensation the first step in the process is not in the brain, but in the nervous extremities. Now in this first step, in the actual production of the impression to be transmitted to the brain, we should suppose the gray matter as necessary as in the production of the impression to be transmitted from the brain in effecting voluntary motion. Else we must conclude, that, while the white substance can have no active agency in the brain, but serves only for transmission, at its other extremity, expanded in the organs, it serves for both transmission and production. Dr. Carpenter supposes, therefore, that there is a sort of gray matter in the expanded extremities of all nerves of sensation. But the microscope has never discovered the existence of this matter in any nervous expansion, except in the nerve of the eye, in the retina, and in some parts of the internal ear. And some facts seem to militate against Dr. Carpenter's view of the subject. If, for instance, you hit the trunk of a nerve, as the little nerve so often hit at the elbow, a sensation is produced, which is in some measure referred to the part to which the nerve is distributed. From such facts it would appear, that in sensation the white nervous matter does not merely transmit impressions, but has an agency also in originating them. There is then probably

no gray matter ordinarily in the expanded extremities of a nerve, but they are merely terminations of the tubes which make up its trunk.

235. The cells which form the peculiarity of the structure of the gray substance are often, as you saw in Fig. 69, of very singular appearance from their prolongations. They lie in the interstices of a vascular network. A due supply of arterial blood is absolutely essential to the vigorous performance of the functions of the gray substance. If the supply be cut off in any way, as by the failure of the heart's action in fainting, insensibility and the loss of the power of motion are the consequence. While the gray substance is on the outside of the brain, it is on the inside of the spinal marrow. It is also on the inside of the little bodies called *ganglions*, scattered here and there, as depositories of nervous force, or as little brains, as we may term them. These ganglions are not merely a part of the apparatus of communication. They are different from plexuses, which are mere combinations of nervous trunks, as seen in Fig. 77, *t t* being the trunks, which, after uniting with

FIG. 76.

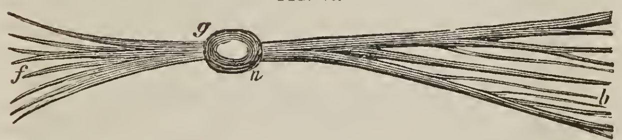
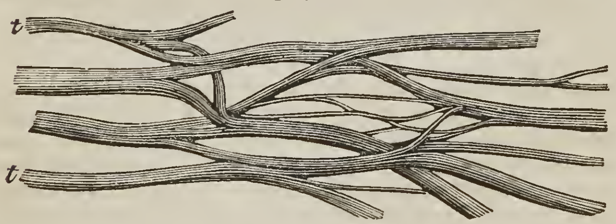


FIG. 77.



each other in various ways, again separate to go to their different destinations. At *g*, in Fig. 76, is a ganglion into which the fibres *f* of the nerve *n* run. It then divides again into branches *b*. These ganglions *produce* nervous force, and therefore are composed like the brain in part of gray substance. The spinal marrow, too, produces as well as transmits, and so

this substance forms a part of it. This gray substance, as it is in constant operation, is subject to much wear and tear, as we may express it, and therefore the changes of repair are constantly going on in its structure. Hence, the necessity for so large a supply of blood, as is secured by the network of vessels, among which the cells peculiar to this substance are scattered. The microscope has fully demonstrated the reality of these continual changes, for it shows us, whenever a portion of this substance is examined by it, the cells in all the various stages of development mingled together. The freshly made simple cells are seen among those which have been formed for some time, and which have put forth their long off-shoots, as seen in Fig. 69.

236. The extremities of the fibres, or rather of the tubuli (Fig. 75) of the nerves terminate variously. The most common termination is in loops, as seen in Fig. 78, which represents the

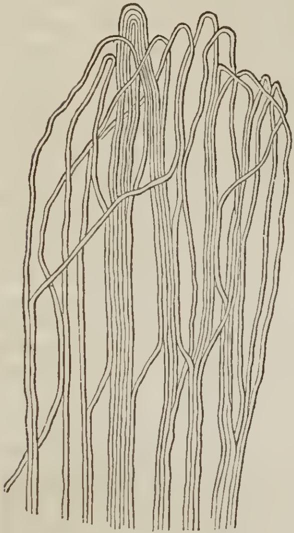
FIG. 78.

NERVES OF TOUCH IN THE SKIN OF THE THUMB.

termination of the nerves as seen through the microscope in a thin perpendicular section of the skin in the thumb. The three eminences in this figure are those of the *papillæ*, as they are termed, which you can see are arranged in curvilinear rows, if you look at the ball of the thumb. In Fig. 79 you see this same loop-like arrangement in the nervous tubuli, as seen through the microscope, on the sensitive sac that lines the cavity of a tooth, the entrance for the nerves and bloodvessels of this sac being at the end of the root.

237. One very singular termination of the nervous tubuli, is in what are called Pacinian corpuscles, after Pacini, the first microscopist that discovered them. They are found attached to the nerves in the hand and foot more often than any where

FIG. 79.



NERVES IN A TOOTH.

FIG. 80.

PACINIAN CORPUSCLES.

else. Their structure, which is seen in Fig. 80, A, highly magnified, is very curious. They are attached to the branches of the nerves on which they cluster by little peduncles or stalks. At *a* is the peduncle; *b* is the nervous fibre or tubulus; *f* is its termination in the corpuscle. The corpuscle itself is composed of layers of a very delicate fibrous membrane inclosing each other like the coats of an onion, to the number of sometimes sixty, the inner ones, *d*, being closer together than the outer ones, *c*, are. In B is represented a portion of a nerve of a finger, with clusters of these corpuscles of about the natural size. Of what use these singular bodies are we know not. But the fact that they are always found in certain regions of the body shows that they are placed there for some definite purpose. It has been supposed by some that they are minute electrical batteries, because they bear some resemblance to the electrical organs found in some fishes.

238. There is a wonderful fact in regard to the healing of wounded nerves which must not pass unnoticed. You know

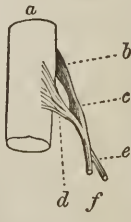
that if a nerve be divided, all communication between the part that it supplies with branches and the brain is cut off. No impressions can be transmitted through it to and from the brain. But the two cut ends of the nerves can grow together, and the communication can thus be more or less restored. Sometimes it is as perfect as before. Now, if you call to mind the structure of a nervous trunk, you will see that this is passing wonderful. It is made up, you will recollect, of tubuli which are entirely separate from each other, and each one of these goes from its origin in the nervous centre to its destination by itself. It is difficult to conceive, therefore, how the nerve can be healed without creating confusion. For to avoid this it would seem to be necessary, that each little tube at its cut end must unite with its corresponding end, and not with the end of some tube with which it has no relation. For example, if the nerve distributed to the hand were cut, it would not do, as it seems to us, to have tubuli which go to the thumb unite with those which go to a finger. And besides, as I shall soon show you that the tubuli, through which the impression that produces motion is transmitted, are separate from those which transmit the impression that causes sensation, it would not do for a tubulus of one kind to unite in the healing with one of the other kind. We can not conceive how a confusion in sensations and motions can be avoided, unless the end of each fibre or tubulus is united with its corresponding end; and such an accurate union of the multitude of tubuli in a nerve seems an impossibility. That there is, however, a very accurate union effected, is manifest from the observations of M. Brown Sèquard. He examined in animals nerves which were divided twelve months before, and could not discover the point of division even with the aid of the microscope. If the tubuli were not all made as perfectly continuous as before the nerve was divided, the microscope would have revealed the defect. But it takes time to effect this adjustment of the tubuli, for it was found by Dr. Haighton in his experiments nearly fifty years ago, that after dividing nerves, their functions were not restored till some time after they were apparently healed. This shows most clearly, that the arrangement of the tubuli, which is required for the communication of impressions through them, is gradually effected after the union takes place.

239. Taking this view of this interesting point, the difficulty is greatly enhanced, when we look at the union of parts that

did not originally belong together, as, for example, when a piece of skin is dissected from the forehead, and is twisted down so as to be made to grow on to the nose to supply a deficiency there. Here new relations entirely are established between the nerves of the divided parts, and, as we should expect, there is confusion in the sensations. The patient, at first, whenever the new part of his nose is touched refers the sensation to the forehead. But this confusion of the sensations is after a while removed. And it is curious to observe, that while the old nervous connections are breaking up, and the new ones are becoming established, there is an interval of partial, sometimes entire, insensibility in the part. How these new relations can be established consistently with the known arrangement of the tubuli in the nerves is a mystery.

240. As I have already hinted, there are different nerves for different purposes. The nerves through which the mind sends its messages to the muscles, are not the same with those through which it receives impressions in sensation. In and about the face, the nerves of motion and sensation are, for the most part, entirely separate from each other. But in other parts of the body, the fibres or tubuli for motion and sensation are mingled together in the same nervous trunk, inclosed in one sheath. It is found that each of the nerves, coming out from each side of the spinal marrow, has two roots, which unite together and are inclosed in one sheath. This arrangement is represented in Fig. 81, in which *a* is a portion of the spinal cord; *d* the anterior root; *b* the posterior root; *e* the trunk formed by the union of these two roots; and *f* a branch of the nerve. At *c*, on the posterior root is one of the ganglions, or little brains, of which I spoke in § 235. Why they are placed on these posterior roots, and not on the anterior, or why they are placed here at all, we know not. It has been ascertained by many experiments on animals, that the posterior roots are composed of tubuli, which bring impressions *to* the spinal marrow; while the anterior are composed of tubuli which carry impressions *from* the spinal marrow. For, if the spinal cord of an animal be laid bare, and a posterior root be irritated, pain is produced; but if an anterior root be irritated, violent motions are caused in the parts to which the nerve is distributed. That is, the

FIG. 81.



SPINAL CORD.

posterior root is a nerve of sensation, and the anterior a nerve of motion. It is a mere matter of convenience that they unite, and are mingled together in the same sheath, for they are to be distributed in the same parts. In and about the face the nerves of motion and sensation are kept for the most part separate, as before stated, merely because it would be no convenience in any case to put them together in one sheath.

241. But not only are there different nerves for sensation and for motion, but there are also different nerves for different kinds of sensation. Thus, in the eye, the optic nerve which transmits the impressions from the images formed on the retina, as will be shown in the Chapter on the Eye, is wholly separate from the nerve by which any pain or irritation is felt in this organ. The latter is called a nerve of *common* sensation—the former a nerve of *special* sensation. So in the nose, the nerve that takes cognizance of odors is a different one from that by which irritation on the same membrane is felt. The snuff-taker smells the snuff with one nerve, and feels its tingling with another.

242. The nerves devoted to one kind of sensation can not in any case perform the function of those of any other kind. Each nerve is fitted for its own peculiar office, and has for this its own peculiar susceptibility. Thus, the nerve of touch is insensible to light, and, on the other hand, the nerve of vision is insensible to touch. If, therefore, the nerve of vision be paralyzed, but the nerve of common sensation in the eye be unimpaired, although there is no seeing, the eye is as sensible to irritation as ever. On the other hand, if the nerve of vision be unimpaired, and the nerve of common sensation be paralyzed, as sometimes happens, the individual can see, but he has lost the sentinel that stands guard over the eye, and by its warning of pain keeps it from injury. What, therefore, is flying in the atmosphere may lodge in the eye, and though it produce no pain, it will excite inflammation by irritating the capillaries. The eye in some of these cases is destroyed, by the inflammation which thus arises from the loss of sensibility to the touch. When the nerve of common sensation is in a healthy state, the moment any thing gets into the eye great pain is produced, and the tears flow and the eyelids are in constant motion; and if by these instinctive means, as we may term them, the irritating substance is not removed, other means are at once resorted to. But when this nerve is paralyzed, although the irritating substance produces no pain, it

gradually causes inflammation in the delicate vascular texture of the eye. Pain, then, in this case, as well as in every other, is a safeguard against danger. The part is endowed with an acute sensibility to touch, because it is needed as a sentinel in a part so delicate and yet so exposed.

243. This leads me to remark, that the different parts of the body are endowed with different degrees of sensibility, according to their necessities, in relation to the warning of danger. Accordingly, the skin is the most sensitive part or organ of the body, that it may warn at once of the approach of danger; while the internal parts have much less sensibility, some of them none. In the performance of operations, therefore, the great suffering is in the cutting of the skin. There is very little sensibility in the muscles, and there is none in the bones. The following fact illustrates the use of the sensibility of the skin in the prevention of injury. A man who had lost all sensibility in his right hand, but retained the power of motion, lifted the cover of a pan when it was burning hot. Although he was not aware of any effect at the moment, the consequence was the loss of the skin of the fingers and of the palm of the hand, laying bare the muscles and tendons. If the sensibility had not been lost, that is, if the nervous tubuli which transmit sensation had not been paralyzed, the warning of pain would have been instantly given to the brain, and orders would have been sent to the muscles to relax their grasp of the cover; and so rapid are these transmissions, that the cover would have been dropped soon enough to prevent any great amount of injury from being done.

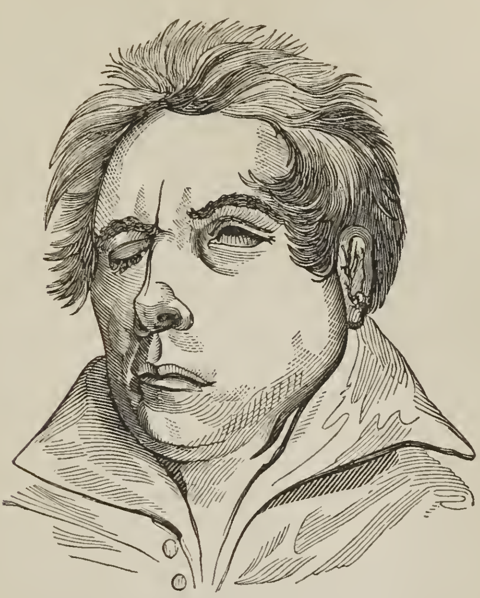
244. Although there is so little sensibility in the internal parts in their healthy condition, yet when they become inflamed they become sensible of pain, sometimes acutely so. Thus, an inflamed bone is the seat of severe pain; and the tendons, although nearly insensible ordinarily, become very painful when inflamed, as any one that has a deep-seated felon can testify. The question as to the cause of this change of sensibility I will not stop to discuss, but that there is a benevolent object in it is very manifest. If inflammation caused no pain in such parts, it might go on to a destructive extent without the person's being aware of the danger, and therefore without his applying for medical means.

245. It was formerly supposed that a nerve must of course have an exquisite sensibility. But there is no sensibility in nerves devoted to motion. Neither is there any in the brain

itself. Portions of it can be cut off without producing any pain. The heart, too, is insensible to the touch. A case proving this fell under the observation of Harvey, the discoverer of the circulation of the blood. A young nobleman, from an injury received in a fall, had a large abscess on the chest, which occasioned such a destruction of the parts, as to leave the lungs and heart exposed. Charles I., on hearing of the case, desired to have Harvey see it. "When," says Harvey, "I had paid my respects to this young nobleman, and conveyed to him the king's request, he made no concealment, but exposed the left side of his breast, when I saw a cavity, into which I could introduce my fingers and thumb; astonished with the novelty, again and again I explored the wound, and first marveling at the extraordinary nature of the case, I set about the examination of the heart. Taking it in one hand, and placing the finger on the wrist, I satisfied myself that it was indeed the heart which I grasped. I then brought him to the king, that he might behold and touch so extraordinary a thing, and that he might perceive, as I did, that unless when we touched the outer skin, or when he saw our fingers in the cavity, this young nobleman knew not that we touched his heart!" This absence of sensibility in the heart is not because it is not well endowed with nerves. It is well endowed, but it is with nerves which are devoted to another purpose. They are nerves of sympathy, which establish a connection with every part of the body, making this organ to be so easily affected by motion, by disease, and by every passing emotion in the mind.

246. In the face we have an example of different sets of nerves for different classes of motions. All those motions that are used in the expression of the countenance are associated together by a certain nerve. This nerve has nothing to do with other motions, as mastication. Other nerves are provided for them. Sometimes this nerve of expression is paralyzed on one side. The result is, that while the individual can masticate equally well on both sides, he can laugh, and cry, and frown, only on one side, and he can not close the eye on the side affected. In Fig. 82 is a representation of this condition of things. The left eye can not be closed by any effort, and the left side of the face is wholly devoid of expression. This nerve of expression is often paralyzed by itself, the other nerves in the neighborhood, both nerves of sensation and of motion, being entirely unaffected. This nerve has been called the *respiratory*

FIG. 82.



PARALYSIS OF THE NERVE OF EXPRESSION
on one side of the face.

nerve of the face, because it controls motions which are connected with the movements of respiration. If you observe how the various passions and emotions are expressed, you will see that there is a natural association between the muscles of the face and those of the chest in this expression. This is very obvious in laughing and in weeping. But this association can be effected only through nervous connections. And these connections in this case are very extensive and intimate. When the nerve of expression, or facial respiratory nerve, is paralyzed, all the motions of the face connected with the respiration are absent. Though the individual may sob in weeping, or send forth the rapid and successive expirations of laughter, yet the face on the side where the nerve is paralyzed will be perfectly quiescent. So, too, those movements of the nostrils which are sometimes used in expression, can not be performed. Sneezing and sniffing up can not be done

on the affected side. Neither can the individual whistle, because a branch of this nerve goes to the muscles at the corner of the mouth, which are therefore disabled, Sir Charles Bell, in cutting a tumor from before the ear of a coachman, divided this branch of the nerve. Shortly after, the man thanked him for curing him of a formidable disease, but complained that he could no longer whistle to his horses.

247. The eye has six different nerves, each for a different service. 1. The optic nerve. This has nothing to do with the motions or the common sensations of the eye. Its sole office is to transmit impressions from the images formed in the eye to the brain. 2. A nerve of *common* sensation, by which any irritation in the eye is felt. 3. A nerve which is distributed to the muscles of the eye generally, and to no other parts of this organ. 4. A nerve which goes to one particular muscle, one of the oblique muscles of the eye. It is an involuntary muscle which performs the insensible rolling motions of the eyeball, and is associated with the muscles of expression in the countenance by means of nervous connections. 5. A nerve which goes to another single muscle, which turns the eye outward. 6. A branch of the respiratory nerve, which regulates the motion of the eyelids, and has much to do, therefore, with the expression of the countenance. To this small organ, then, are distributed six different nerves, each having its distinct office, and its separate origin in the brain. How various are the transmissions through these nerves, and how nicely adjusted must all the parts of this complicated apparatus be, that each may perform its office without interference with the rest!

248. I have already alluded incidentally to the fact, that one nerve may be paralyzed, and others distributed to the same parts may be entirely unaffected. Thus the nerve of expression in the face may be paralyzed alone, the face retaining its usual sensibility and its power of performing other motions than those of expression, as mastication, because the nerves of common sensation and of common motion are untouched by the disease. So, too, in the nerves which go out from the spinal marrow, composed of tubuli of motion and sensation mingled together, one set of the tubuli may be affected while the other is not; for in paralysis it is often the case that the sensibility remains while the power of motion is gone, and *vice versa.* Sir Charles Bell relates an interesting case, in which the paralysis was different on the two sides of the body. A mother was seized with a paralysis, in which there was a loss of muscular power

on one side, and a loss of sensibility on the other. She could hold her child with the arm of the side which retained its power of motion but had lost its sensibility. But she could do it only when she was looking at it. She could not *feel* her child on the arm, and therefore when her attention was drawn to any thing else, and she ceased to have her eyes fixed on the child, the muscles having no overseer, as we may say, to keep them at work, were relaxed at once, and the child would fall from her arm. In this case, bound up in the same sheaths were two sets of tubuli, one set of which were useless in the nerves on one side of the body, and the other set were useless in the nerves of the other side.

249. We should suppose that there would be a difference in the construction of the nerves, corresponding with the different uses to which they are devoted. But it is not so. The microscope shows us that the nerves of motion and of common and special sensation are all alike in their structure, and chemistry shows us that they are alike also in their composition. The question arises, then, why the impression producing motion can not be transmitted by the same nerve with the impression causing sensation. The reason is evidently not to be found in the nervous trunk itself, as this is the same in all cases. It is in the circumstances of the two *ends* of the nerve—that which is in the nervous centre from whence it arises, and that which is expanded in some part of the body. You can see at once that the nervous tubuli which end in the fibres of a muscle can not transmit sensation to the brain from the skin over the muscle, because they do not go to the skin at all. There are other tubuli that are distributed there for that purpose, mingled indeed in most cases with the tubuli for motion, but yet kept entirely distinct from them. And besides, there is probably something in the mode of arrangement of the extremities of a nerve of sensation, which differs from that which exists in the distribution of a nerve of motion, so as to make it impossible for a nerve of motion to receive the impression producing sensation, even where the impression is made directly upon the muscle itself. There is also probably a different ending of the nerves of sensation and motion in the nervous centre, the brain, or spinal marrow, that makes the one kind incapable of performing the duties of the other kind.

250. There have been many hypotheses in regard to the action of the nerves. The most common theory, even up to modern times, was this—that the brain is not only the great

centre of the nervous system, but its central workshop, as we may express it, and that in it is secreted a nervous fluid, which is distributed through all the body by the nerves, they being, as it was supposed, bundles of conduit-pipes. This fluid was supposed to move back and forth in the nerves, going outwards towards the extremities of the nerves to excite motion, and going inward to the brain to convey the sensation of external impressions. This theory has been exploded by the researches of Sir Charles Bell and others, and during the last half century important and numerous discoveries have been made, in relation to the functions of different parts of the nervous apparatus. And though there are many things in this system, which links the spiritual with the physical, that we shall never understand, the bounds of our knowledge in regard to it are undoubtedly to be largely widened by future researches.

251. It is a favorite idea with some physiologists that nerve-force, as it is termed, is identical with electricity, and that the nervous system is therefore a system of electrical batteries, with an apparatus for a sort of telegraphic communications. They ground their opinion upon the fact, that a current of electricity passed along nerves may produce motion or sensation, according to the character of the nerve through which it is passed, and also upon the analogy which exists between nerve-force and electricity in the instantaneousness of their transmission. But facts and experiments have wholly disproved this alleged identity. Some of these I will briefly relate. Mechanical and chemical stimuli produce the same nervous action that electricity does. This shows that the electricity acts merely as a stimulus to wake up the nerve-force, instead of being that force itself. Experiments have been tried, to detect, if possible, the existence of an electrical current in a nervous trunk while the parts to which it is distributed were in action, but in vain. Thus, Prof. Matteucci laid bare the large nerve of the leg of a horse, and although by irritating its roots he excited powerful action of the muscles of the leg, the instrument in connection with the nerve was entirely unaffected, though it was so extremely delicate that it would indicate an infinitesimally small disturbance of the electrical equilibrium. Again, a ligature put around a nerve will by its compression prevent nervous transmission through it, but will not hinder the passage of an electrical current. Still again, if a piece of a nerve be cut out, and some good conducting substance be introduced in its place, electricity will pass, but there can be no transmission of nerve-

force to the parts below the division. Besides all this, nerve-force differs from electricity in the fact that it can be confined to the nervous trunk, or even to a small portion of the trunk, as when a motion is very limited in extent; while electricity not only passes through the whole trunk, to all the parts to which the nerve is distributed, but is diffused in the parts around it. Thus, if an electrical current be passed through the main nerve of the limb of an animal, it will go through every branch of that nerve, and cause all the muscles of the limb to contract; but nerve-force may be so insulated in a small portion of the nerve, that a single toe may be moved alone. And some of the electricity will be diffused at once in the muscles and other parts around the trunk of the nerve before it reaches any of the branches that go off from it. Indeed, the muscles are much better conductors of electricity than the nerves, which should not be if the nerves were particularly designed for its transmission, as the hypothesis would claim. And both muscles and nerves are nothing like as good conductors as a common copper wire.

252. We have thus far contemplated nervous action, for the most part, only in two forms—as producing sensation and voluntary motion. In sensation the action is from the extremity of the nerve to the nervous centre; but in motion it is from the centre to the extremities of the nerves, as they are expanded among the fibres of the muscles. This voluntary motion, you see, may arise in consequence of sensation, as when you withdraw the hand from the fire, if the heat be painful; or it may occur without a preceding sensation, as when the thinking mind wills to perform certain motions for effecting some purpose. In either case it is supposed that the gray vesicular or cellular substance of the brain is in immediate connection with the mind, and that the white tubular matter of the brain and the nerves serve only for transmission. That is, both in sensation and motion the effective physical agency is in the vesicular gray substance. This is the working part of the telegraphic apparatus of the mind, while the innumerable tubuli of the white matter of the brain and nerves are the communicating wires.

253. Much of the muscular motion of the body is produced without the agency of the will, and sometimes even in opposition to it. This is true of the motions caused by emotions in the mind. For example, the muscular motions in sobbing and in laughing often occur in opposition to the strong action of the

will. In this case, the emotion produces its effect upon the gray vesicular substance, and from this the impression is transmitted through the nerves to the muscles.

254. There are some common motions which are performed to a greater or less extent without the agency of the will. The muscles which perform them are called involuntary muscles. The muscles of respiration, for example, ordinarily act without our willing them to do so. If they did not, respiration would stop when we sleep, or become stopped from disease. But the will can quicken these muscles in their action. They are therefore not wholly involuntary. But there are some purely involuntary muscles. The muscular coat of the stomach, which I spoke of in the Chapter on Digestion, as being constantly in motion when the stomach is filled with food, is of this character. No effort of the will can quicken or retard the action of this muscle. That exceedingly compound muscular engine, the heart, is a collection or arrangement of purely involuntary muscles. No effort of the will can directly influence its motions, though it may do it indirectly, by so directing the thoughts as to awaken emotions calculated to produce this effect. That beautiful circular curtain in the eye, the iris, has the size of its circular opening, the pupil, controlled, as you will see in the Chapter on the Eye, by an involuntary muscle.

By what agency, you will inquire, are these involuntary motions produced? The answer to this question will open to you a new view of the nervous system.

255. I have already alluded to the two roots which unite to make up each nerve that comes from the spine. One of these roots is composed of tubuli through which impressions are transmitted to the spinal marrow; and the other contains tubuli, through which an impression is transmitted from the spinal marrow to the muscles, causing them to contract. Each nerve, then, coming from the spine, is made up of two distinct nerves, or two distinct sets of tubuli. One of these is called an excitor nerve, the other a motor nerve. In the case of the muscles of respiration, every time that they act, the process is this—an impression is transmitted from the lungs through an excitor nerve to the spinal marrow, the gray vesicular substance there responds to this impression, and sends in consequence an impression by a motor nerve to the muscles. So in the case of the iris, which contracts to prevent too much light from entering the eye, the light as it strikes the retina produces an impression, which is transmitted through an excitor nerve, and

in consequence another impression is transmitted through a motor nerve to the iris. So also, the presence of food in the stomach produces an impression which is transmitted through the excitor nerve, and another impression is returned through the motor nerve, exciting the muscular coat to action. And in the act of swallowing an impression is transmitted from the food thrust back into the throat, and then impressions are returned to the many muscles engaged in this compound act, (§ 78). The action of the nerves illustrated by these examples is termed their *reflex* action, because the impression transmitted by one nerve *to* the spinal marrow is *reflected from* it by another.

256. You see that I use the rather indefinite word, *impression*, in relation to the transmissions through the nerves. It is the best word that can be employed, because although something is transmitted, we know not what that something is. The result of the transmission is different in the excitor nerve from what it is in the motor nerve. The result differs also in the excitor nerves according to circumstances. In some cases it is accompanied with actual sensation, while in others it is not. That is, the brain sometimes participates in the result, and sometimes it is confined to the spinal marrow. Thus, in the act of respiration, the impression carried from the lungs by the excitor nerves comes from the presence of dark blood in the lungs. Ordinarily, a mere impression, and nothing like sensation, is transmitted. The respiratory muscles, most of the time, go on to do their work, in obedience to the impressions communicated from the lungs, without the process being recognized by the mind. But when there is embarrassment in the lungs, the quiet process, carried on through the agency of the spinal marrow alone, is not adequate to meet the exigency. In some way, the brain becomes a party in the operation. The act of breathing is now accompanied with positive sensations, and there is a mixture of voluntary and involuntary muscular action. So, also, the ordinary movements of the stomach are attended with no positive sensations. That is, there is no transmission to the brain of any impression of which the mind takes cognizance. But if there be disturbance there, and extraordinary movements are produced, then cognizance is taken of them, and sensations of various kinds result.

257. The spinal marrow, in relation to the involuntary muscles, seems ordinarily to be in a great measure independent of the brain; while on the other hand, in relation to voluntary

motion and sensation, it forms the chain of communication between the brain and the moving and sentient parts. In this respect the dependence is perfect. In injuries of the spine, therefore, the extent of the loss of the power of motion and of sensibility depends on the nearness of the injury to the brain. The higher up the injury is, the larger is the number of nerves whose connection with the brain is cut off, and therefore the greater is the extent of body rendered insensible and motionless.

258. The spinal marrow then performs two separate functions —one, in producing involuntary motion, as an organ by itself; and another, as an organ in connection with the brain, in the production of voluntary motion and sensation. The arrangement, by which it does two things which are so different from each other, will be clear to you, if you bear in mind the fact that the spinal marrow, like the brain, is composed of the two nervous substances, the white tubular, and the gray vesicular substance. When the spinal marrow acts as a mere medium of communication for the brain, the transmission is made directly through the tubes of the white substance to and from the brain —*to* the brain in sensation, and *from* it in voluntary motion. Thus, when a sensation is felt in the foot, the impression made there is transmitted through the nerve to the spinal marrow, and up through the white part of this organ to the brain. It touches none of the gray substance of the spinal marrow, but goes to the gray substance of the brain. And when the foot is moved, an impression is returned from the brain through the white part of the spinal marrow, and then through the nerve which goes from it to the muscles that move the foot. But, on the other hand, when the spinal marrow acts by itself, independently of the brain, producing what is called reflex action, (§ 255,) the impressions that are transmitted, some of them begin, and some end in the gray substance of the spinal marrow. The impression on an excitor nerve ends there, and the impression on a motor nerve begins there, the latter resulting from the former, except when motion is produced by disease in the spinal marrow itself. Thus, in breathing, as described in § 255, an impression goes from the lungs through excitor nerves to the gray substance, and that is the end of it; but another impression begins there as a result of it, and is transmitted to the involuntary muscles moving the chest.

259. One marked distinction between the brain and spinal marrow is, that the brain has its intervals of rest; but the functions of the spinal marrow never cease for a moment as

long as life continues. In sleep the brain is more or less at rest, and it is in a state of entire torpor when the sleep is profound. But during sleep the heart beats, the respiratory muscles work the chest, and the muscular coat of the stomach churns the food if there be any there. For these motions, with many others, are dependent upon the spinal marrow, and not upon the brain; and so, while the brain sleeps, the spinal marrow keeps up the operations of the system that are essential to the continuance of life, in the manner described in § 255. So, also, in apoplexy, when the brain is torpid from the pressure of blood, the spinal marrow, being unaffected, keeps up the functions of those organs which are dependent upon it. But besides the motions that I have mentioned, as being kept up by the spinal marrow, when the brain is torpid from any cause, there are other motions which can be excited by stimulating nerves that are connected with the spine. For example, the act of swallowing can be produced by pouring a liquid into the mouth, and motion can be produced in the muscles of a limb by irritating the limb at different points. If you cut off the head of a frog, and thus destroy all sensibility, you can produce movements in his limbs by irritating them. You can, indeed, make the whole body to move together, by producing irritation at many points at the same time. So, too, if a man be paralyzed in his lower limbs by a blow upon the spinal column, these parts, which he cannot move by his will, can be excited to motion by irritation with electricity or other agents.

260. The motions of the muscles in convulsions are produced by the agency of the spinal marrow. The irritation causing them sometimes exists in the spinal marrow itself, being the result of disease there. But commonly the irritation is in some other part of the system, and it produces the convulsive movements by sending an impression through excitor nerves to the spinal marrow, to be reflected back through the motor nerves, as described in § 255. The brain during the convulsion is in a torpid state, the individual being unconscious. That the brain is involved to some extent in the convulsion is very clear, and sometimes the cause of the convulsion is in this organ. But it is probable that the convulsive *movements* are directly dependent on the spinal marrow, and that even when the cause is in the brain, it is by the action of the spinal marrow, sympathizing with and affected by the diseased brain, that the convulsion is produced. And when

the cause is in some other part, as in the irritation of teething or indigestion, the impression is sent directly to the spinal marrow, and is reflected from it to the muscles, the brain being only secondarily affected.

261. It is worthy of remark, that in convulsions there is a purely *involuntary* action of muscles, that are ordinarily under the control of the will. How is this? How are they taken away from the usual control of the will so suddenly and so entirely? It is not possible that any temporary new connections can be established all at once by the disease,—that there is, to use illustrations of a familiar character, a sort of unshipping of the usual connection, and a hitching on of another for the time being, or a switching off from one track on to another. These voluntary muscles must have all the time a connection with the gray substance of the spinal marrow, just as the involuntary muscles have, only it is not as intimate and extensive. If it were not so, they could not act occasionally as involuntary muscles. Being thus connected with the gray substance, both in the brain and spinal marrow, when they act in obedience to the will, the impression exciting their action comes to them from the gray substance in the brain through the white part of the spinal marrow; but when they act involuntarily, the impression comes from the gray substance in the spinal marrow, and not from the brain.

262. I may remark farther, that the voluntary muscles act involuntarily more often than is commonly supposed. As already stated, (§ 259) in animals, from which the head has been removed, the voluntary muscles can be excited to involuntary action, resembling voluntary movements, although of course with the removal of the head were destroyed all sensation and all exercise of the will. And in the case of the man paralyzed by injury in the back, alluded to also in § 259, involuntary movements can be excited in the voluntary muscles. A pigeon, whose cerebrum had been removed, would fly when thrown into the air, would run when it was pushed, and would drink when its beak was put into water. There was no sensibility and no will in this case, for they can not be without the cerebrum. The movements were involuntary, though performed by voluntary muscles. Now as these facts prove that voluntary muscles are, through their connection with the spinal marrow, capable of acting as involuntary muscles also, the question arises, whether they do not much of the time act in part as involuntary muscles, and sometimes wholly so. That

this is the case, a little reflection will show. When we are walking we use voluntary muscles. But manifestly a distinct act of the will is not put forth for every motion performed in walking. The mind may be at the same time fixed upon something else; and there seems ordinarily to be only an occasional action of the will, as when we change our course, or when some obstacle is in the way, requiring a variation from the regular consecutive series of movements. There is a distinct action of the will when the movements begin; but after this the motions seem for the most part almost automatic, and are probably produced by the reflex action of the spinal marrow, the will interfering only when occasion requires. This is more manifestly the case when one is walking in a reverie, and perhaps finds himself on awaking from it, in a different place from that to which he had willed to go. It is as if the brain set the machinery of the limbs to work, and then delivered it over to the care of the spinal marrow, interfering only when it needs to do so to meet some difficulty, or when it wishes to give a new direction to the movement, or to stop it. And in a reverie, the brain occupied with other things, neglects even to exercise this superintendence, and leaves the machinery wholly to the guidance of the spinal marrow. The same remarks can be made in regard to other motions, as in speaking, singing, playing on an instrument, &c. In all these cases the voluntary muscles act in some measure involuntarily, being governed by an association in their action which is far from being wholly dependent upon the brain, and the direction of the will. I shall recur to this point again, when I come to treat of the connection between the mind and the body.

263. Many experiments have been tried upon animals in reference to the functions of the brain, and of the spinal marrow. I have already alluded to some of them. It was formerly supposed, that the brain was the only centre of nervous power, and that it was immediately essential to the preservation of life. But these experiments have shown that this is far from being the truth. The brain, it has been found, has nothing to do directly with the maintenance of life. Animals live for some time after the brain is destroyed. A pigeon was kept alive for some months after its cerebrum was removed. Its condition was very much like that of a man, the functions of whose cerebrum are suspended by the pressure of a fractured portion of the skull. Although, like him, the animal had lost all sensation and voluntary motion, yet, like him, it

continued to breathe, and its heart continued to beat. Of course so extensive an injury of so important an organ will at length cause death; but life continues long enough in such cases to show, that this organ is not immediately essential to its continuance. The functions most essential to life, the respiration and circulation, are, as you have seen, kept up by the spinal marrow. The very upper part of this organ is especially devoted to this purpose. You may take out the brain of an animal, and destroy all its spinal marrow, except this upper portion of it, and the animal will still breathe, and its heart will beat. But if you destroy just this small portion of the spinal marrow, though you leave the rest of it and the brain untouched, the animal will die at once from the cessation of the respiration and the circulation. In the Spanish bull-fight, when the matadore at length kills the animal, by adroitly piercing the spine in the back of the neck, he inflicts his wound upon this upper part of the spinal marrow.

264. If after cutting off the head of a frog, you divide the spinal marrow in the back, you can produce involuntary motions in both the upper and lower extremities. But you can not produce them at the same time in both together, for the division of the spinal marrow in the back separates it into two independent parts. When, therefore, you irritate the upper extremities, the motion is confined to them, and the lower extremities are quiescent. And if you irritate the lower extremities, the motion produced there does not extend to the upper. The division can be carried much farther with similar results. If the spinal marrow be divided above and below where a pair of nerves is given off, so as to separate this point wholly from the rest of the nervous system, the reflex action can be excited in the nerves connected with this point. That is, an irritation of the parts supplied by the excitor nerve of this little segment of the spinal marrow will produce an impression in that segment, which will be reflected by the motor nerve to the muscles. The gray substance of the spinal marrow may, therefore, be regarded as a chain of little brains, in some measure separate from each other. But while there are thus many centres of reflex action, there is only one centre of sensation and voluntary motion, and that centre, the brain, is connected with the mind. Some physiologists have maintained that there is sensation independent of the brain; but it may be considered as most abundantly proved, that it is through the brain alone that the mind feels and acts, or rather that we

know nothing in this world of a sentient and acting mind existing without a brain.

265. The system of nerves which we have been examining is termed the *cerebro-spinal*, from its two great central organs, the brain and spinal marrow. But there is another nervous system, the functions of which are involved in much mystery. It is called the system of the great *sympathetic*, or the sympathetic system. Sometimes it is called the *nervous system of organic life*, because it is so intimately and extensively connected with the nutritive processes; while the system that we have been considering is called the *nervous system of animal life*, because it regulates the functions peculiar to animals in distinction from plants, sensation, and spontaneous motion. While the sympathetic system is thus connected with the nutritive processes, it is also supposed to be the means of effecting the sympathetic connection between different parts of the body, and to act as the medium by which the passions and emotions of the mind produce their effects upon the functions of the different organs. In this system there are many ganglions or little brains, which communicate with each other by nerves. There is a chain of them along in front of the spinal column, and there are two quite large ones in the abdomen. This system has connections everywhere with the cerebro-spinal. The purposes aimed at in the particular arrangements of this system are as yet but little understood, and we probably never shall know as much about it as we shall about the cerebro-spinal system. The arrangement of the sympathetic system differs very materially from the cerebro-spinal. It is a single system, and has no symmetrical arrangement, while the cerebro-spinal has throughout two halves which are precisely alike.

I have thus described the arrangements and functions of the nervous system to such an extent, as will prepare you for the consideration of those subordinate organs, by which the purposes of this system are accomplished. After treating of the organs of locomotion, the voice, and the senses, I shall call your attention again to this system, presenting some views of its uses and connections, which you will then be better prepared to understand.

CHAPTER XI.

THE BONES.

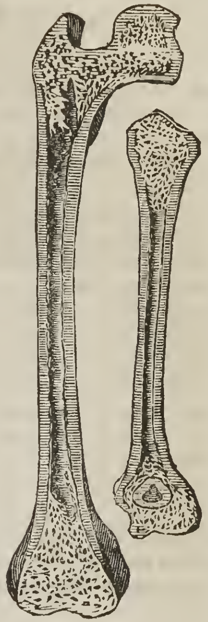
266. The bones furnish the points of support and attachment for the muscles which move the different parts of the body. They are, therefore, the *passive* instruments of locomotion. I treat of the bones before the muscles, because you will then better understand the action and the arrangement of the muscles.

267. The bones, forming the framework of the body, not only furnish points of support and attachment to the muscles, but in many cases serve to defend important organs from injury. Thus, the soft brain is thoroughly secured from harm by being inclosed in the skull; and the lungs are surrounded by walls of bone so arranged, as you saw in the chapter on Respiration, that, while they defend the lungs from external violence, they secure a wide range of motion for the necessary expansion of these organs.

268. The bones are composed of two parts, the earthy or hard portion, and the animal portion which is soft. Each of these portions, as was stated in § 60, can be obtained separate from the other. These two portions of bone exist in different relative proportions in the different periods of life. In the child the animal portion predominates, while the mineral does in old age. It is a wise provision in regard to the child, for if his bones were as brittle as those of old age, or even as those of middle life, they would be often broken in the falls to which the child in its feebleness and carelessness is subjected.

269. There are some points of interest in relation to the *structure* of bone and its growth. I stated in § 61 that bone is generally formed in cartilage, the cartilage being formed first as a mould for the bone. Bone is deposited in two forms, solid and cellular. In the flat bones, as in the skull, the cellular structure lies between two plates of solid bone. In the long bones the cellular part is at the two ends, and is covered with a thin plate of solid bone, while the shaft is a hollow tube with the bone very much condensed. This arrangement

FIG. 83.

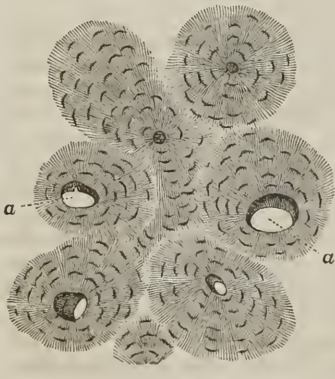


is seen in Fig. 83, representing the thigh-bone and the bone of the arm. Certain well known mechanical principles are observed in this arrangement. The bone would be unnecessarily heavy if it were solid throughout. Lightness in a moving limb is of considerable importance. At the same time strength is to be carefully provided for in a bone which is to sustain the weight of the body, and to which the large muscles of the thigh are attached. By having the bone hollow, both of these objects, lightness and firmness, are secured. The principles involved are recognized by the architect in the construction of pillars, and we see them exemplified in the hollow stalks of plants. The hollow pillar has more strength than the same quantity of matter would have if in one compact mass; and the stalk which supports the full clusters of grain, would break under its load as it moves back and forth in the wind, if it were solid instead of being hollow. But the round cavity of the shaft of the bone does not extend to the ends. These are necessarily large, in order to present broad surfaces for articulation with the neighboring bones; and strength and lightness are secured in this case by a cellular arrangement of the bony matter, the outer plate of solid bone being comparatively thin. There is obviously more firmness in the resistance to shocks or pressure, secured in this way, than there would be if the bony matter were all consolidated into a shell containing a cavity.

270. The round canal in the shaft and the cellular structure at the ends are filled with an oily substance called *marrow*. This, like all other fatty substances, is contained in fat cells, as described in the chapter on Cell-Life. The marrow is also present in the cellular structure between the plates of the flat bones. The cavities and the cells in bones have branching

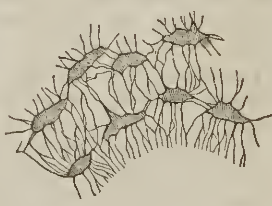
about in them bloodvessels, which are branches of arteries and veins that enter the body of the bone at some particular points, in the long ones near the middle of the shaft. It is from these bloodvessels, together with those that come from the membrane investing the bone, called *periosteum*, that the bone is nourished. But, although an artery runs through the body of the bone, to branch out upon the walls of its cavity, none of its branches enter the very substance of the bone. How then is the bone nourished, that is, constructed and kept in repair? The manner in which the material for this purpose is carried to every point of the solid bone has been developed by the aid of the microscope, and I will describe it to you. If we cut across the solid portion of a bone, and examine it with a microscope, we see here and there orifices of certain minute canals that run lengthwise of the bone. These canals are found to communicate with the cavity of the bone and receive therefore blood, or some of the constituents of the blood, from the bloodvessels which are situated there. These orifices, as seen under the microscope, are represented in Fig. 84. Around these orifices *a a*, you see little dark spots arranged in rings, with lines running to them from the orifices. By magnifying the section of bone still more, we see what these spots and lines are. The dark spots are small cavities, and the lines are minute tubes running to them. In Fig. 85 is a representation of this arrangement as seen in a little portion of the section of bone, more highly magnified than it is in Fig. 84. The

FIG. 84.



SECTION OF BONE.

FIG. 85.



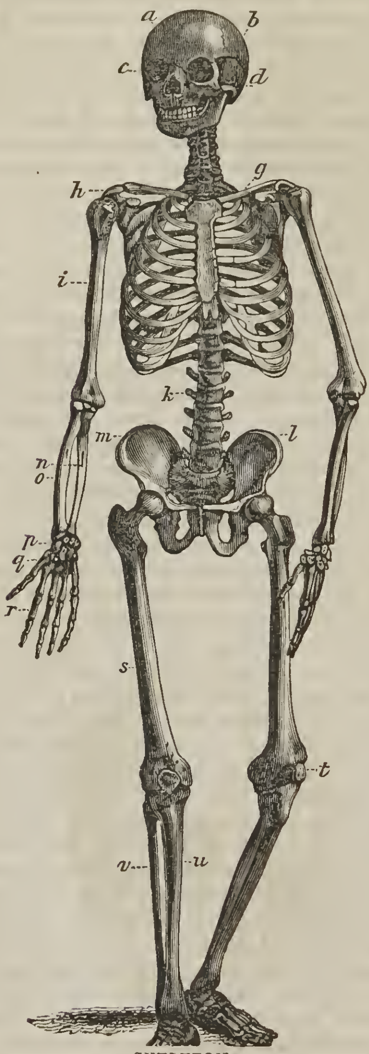
tubes pass out from the canals to the rows of cavities which are around the canals, and thus a circulation is kept up at every point of the solid bone. It is supposed that the blood itself does not circulate in these little channels and cavities in the solid bone, but a fluid containing the constituents of bone. For these channels are too small even to admit the cells which the microscope shows us as swimming in the blood. The fluid that circulates in them is selected from the blood, which is contained in the bloodvessels in the cavity of the bone, and in the periosteum that envelopes it.

271. It is a very common popular notion, that the bones are endowed with great sensibility, and especially the central part, the marrow. The surgeon is very often asked if the sawing of the bone in amputation is not very painful, and if when the saw reaches the marrow it does not produce agony. But the bones have in their healthy state no perceptible sensibility, as I have before stated, and the sawing of the bone in amputation occasions no suffering. When, however, a bone becomes inflamed, severe pain is one of the symptoms. And it is well that it is so; for if it were not, disease might go on to produce disastrous results in a part so covered up by others, without any warning of the danger of the case.

272. The bones are of every variety of shape, to suit the various offices which they are to fulfill. You will see this to be true, as you cast your eye over the skeleton as represented in Fig. 86. You first observe the somewhat round box of bones, which contains the brain, and at the same time furnishes sockets for the eyes, extended irregular surfaces for the apparatus of smelling, and for that of the taste, a place for the organs of hearing, and at its lower part, in connection with the lower jaw, a mill for grinding the food. Then you observe the many bones of the thorax or chest, containing and protecting the heart and the lungs. The *spinal column*, *k*, composed of twenty-four bones, you see as a firm but movable pillar, extending the whole length of the body, and having its base firmly planted upon that stout thick bone, the *sacrum*, which is wedged in so tightly like the key-stone of an arch, between the broad spreading bones on either side. To this pillar are strongly fastened the walls of the chest; and from the chest thus supported by the spine hang the lax front and lateral walls of the abdomen. Then below you see the *pelvis*, as it is called,—a set of large bones so arranged in a bowl-form, as to offer a broad surface of support to the contents of the abdomen.

The bones of the skeleton.

FIG. 86.



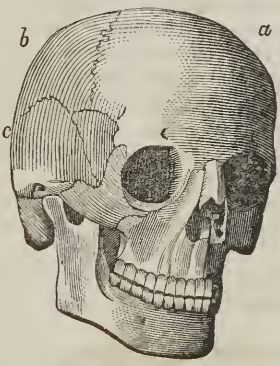
SKELETON.

The bone called the *ilium*, *m* and *l*, on either side, with its flaring upper surface, is especially serviceable in this way. The pelvis also furnishes a socket for the round head of the thigh bone *s*, and points of attachment for the large muscles that move the lower extremity. You observe the large bones of the thigh and leg, intended to give firmness to the lower extremity, and the lighter bones of the arm and forearm, fitted for extent and quickness of motion. And finally, you notice the numerous bones of which the hand and foot are made up, giving them with the intervening cartilaginous coatings, great elasticity, and vast variety of motion, especially in the hand.

273. I will notice with some particularity some of the bones, of which I have given a general description, as they are united together to form the whole skeleton. I can not notice them all, nor dwell upon every point of interest, for this would require much more space than I can devote to the subject. I shall, therefore, select those points which can be made most clear and interesting.

274. I first call your attention to the bones of the head, as you see them in Fig. 87. There are twenty-two bones in the whole head. Fourteen of these belong to the face, while eight belong to the cranium, that is that part of the skull which incloses the brain. Of these, notice particularly the large bone in front called the frontal bone, *a*, making the forehead, and below forming the upper portion of the orbits of the eyes; the parietal bone, *b*, the upper lateral part of the dome of the

FIG. 87.



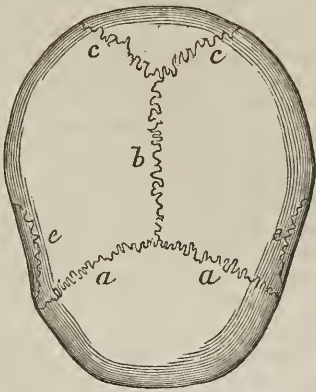
BONES OF THE HEAD.

skull; and *c* the temporal bone on which the parietal bone rests. There is a large bone in the rear forming the back of the cranium as the frontal bone does the front. There are also two bones in the base of the cranium which are out of sight in this view of the skull. You may, perhaps, be disposed to inquire why this box for holding the brain, should be made of so many bones. One reason is, that the enlargement of the skull from infancy to adult age is effected more easily and better than it would be if the cranium were one bone. Another reason is, that even in the adult, in whom these bones are at length so tightly united, violence is less apt to produce injury, from the giving, as it is expressed, of the bones upon each other, than it would be if one bone made the whole structure. And this is especially true of the child, in whom the bones are very imperfectly united. Hence it is that the frequent falls of children upon their heads so seldom do any injury.

275. The principal bones of the head are composed of two solid plates, while the bony matter between these plates is arranged in a cellular or sponge-like form. The outer *table* or *plate* (for both of these terms are used in relation to it) is rather rough, and in some parts has ridges for the attachment of muscles. But the inner plate is very smooth on account of the soft delicate organ that is contained in the cranium. It is so brittle that it has been called the *vitreous* table, from its resemblance to glass in this respect. The modes of the joining of the bones differ in the two tables. In the outer table the joining is by a minute *dovetailing*, called a suture. Numerous little projections from one bone fit accurately into corresponding spaces in the edge of the other. This is very well represented in Fig. 88, in which you see the sutures on the top of the skull; *b* being the suture which is formed between the two parietal bones; *a a*, that between the parietal and the frontal bone in front; and *c c*, that between the parietal and the bone which forms the back of the cranium. A better joining for bones of such a shape as these have can not be conceived of. But the inner table is joined differently. It is so brittle that the small projections of the dovetailing mode of joining would not answer here, for they would break very easily. The joining accordingly is in this case by smooth accurately fitted edges, somewhat beveled, so that one slightly overlaps the other.

276. The upper part of the cranium is in the shape of a dome, and is constructed upon the same principles that such

FIG. 88.



SUTURES IN THE SKULL.

structures are in regard to resistance to pressure or violence. Just as in the domes that are built by man, so in this dome of the cranium, great strength is secured around the lower part, so as to resist outward lateral pressure. In the dome of St. Paul's there is a double iron chain around its base for this purpose, of course concealed from view. In the head of man the dome may be considered as composed of the frontal bone in front, the parietal bones at the side, and the occipital bone in the rear. In front you see the base of the dome strongly fortified, in the heavy arches that form the upper part of the sockets of the eyes, and on the jutting edges of which are the eyebrows. In the rear the base of the occipital bone is very thick, and is fortified with ridges which furnish attachment to the large muscles in the back of the neck. But the most marked and interesting contrivance for the strengthening of the base of this dome is at the side. It is where the parietal bone *b*, as seen in Fig. 87, is joined by the temporal, *c*. The joining here is not by suture, for that would afford no resistance to lateral pressure, either outward or inward. To secure this object, the lower bone, the temporal, laps over the upper, the parietal, with a beveled edge. It abuts upon or against it. It has the relation to the parietal of a buttress to

an arch. You can readily see that when great pressure is made on the top of the head, as when a heavy load is carried there, there must be a tendency to outward lateral pressure at the base of the dome of the cranium, and that this is effectually resisted by the temporal bones acting as buttresses. The same thing is true, also, when a blow is inflicted on the top of the head. And if a blow be received at the side of the head, on the temporal bone, it is evident that the bones will not be so apt to be fractured and pressed inward upon the brain, as they would be, if they were united by suture.

277. You are now prepared to see, to what extent the brain is guarded against the effects of violence inflicted upon the head. These effects come either from fracture of the bones, or from concussion without fracture. In either case the *vibration* of the parts concerned is the cause of these effects. The guards of the brain defend it from injury by lessening or diffusing this vibration. And it is to be observed, that when vibration passes from one texture to another, it loses some of its force in the change. No two substances vibrate just alike; and when a vibration in one is communicated to another, it is modified, and is therefore lessened. Some substances modify and lessen vibrations communicated to them more than others do. If you apply these principles to the effects of violence on the head, you at once see that the brain would be much more apt to receive a dangerous shock from the vibration occasioned by a blow, if its coverings were condensed into one firm and thick layer of substance, than it is now. So also, if the bones of the head were in one solid layer, instead of having two layers, or plates, with the spongy structure between, and the integuments were all consolidated into one thick substance, there would be much more liability to fracture than there is with the present arrangement. Observe now how many, and how various are the textures, through which the vibration of a blow must pass, before it reaches the brain. Outside of the bone there is first the hair; next comes the skin; then there is the cellular membrane containing some fat; then a muscular coat; and lastly, the lining membrane over the surface of the bone. These various textures must deaden very much the force of a blow, and especially the outer cushion of hair, and those inner cushions, as we may call them, of fatty cellular membrane and of muscle. Then, when the vibration reaches the bone, it is lessened by the two plates with the intervening cells, and there is diffused largely among the many bones that unite with

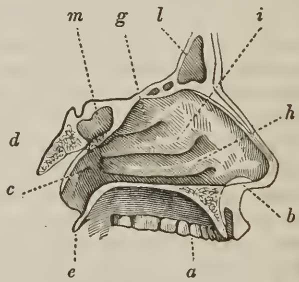
the one on which the force comes. Then as the shock goes into the brain, it is still farther lessened by the membranes which cover that organ. These greatly diminish the vibration, precisely as a coating of leather on the inside of a bell would deaden its vibration when produced by a blow upon the outside. With all these provisions the result is, that comparatively few of the blows received by the head do harm. The skull may be considered as a sort of helmet for the brain, its effectiveness as a defense being very much increased by its coverings and linings.

278. There are some especial guards at particular points in the cranium, where there is much liability to exposure to violence. Thus, as the lower part of the frontal bone, where the eyebrows are, is especially exposed, the distance from the surface to the brain is made considerable by an intervening chamber in the bone, called the frontal sinus. This sinus, which varies much in size in different individuals, is lined with a membrane, and communicates with the nose. You can see that this arrangement is a great protection to the bone at that point. The outer plate could be broken, while the inner is not injured. But the protection which this arrangement affords, is not confined to that single point; it serves also to deaden the vibration of a blow received by any part of the forehead, or by the forehead as a whole. The side of the head, too, is peculiarly exposed to blows. And, therefore, the skull is peculiarly guarded at this point. Beside the overlapping of the temporal bone upon the parietal, to which I have before alluded, the parietal bone is made thicker at its lower part, where it is most liable to be struck, than it is in most of the other parts of it. Then, too, the place of joining of the temporal and parietal bones is covered over by a thick muscle, the contractions of which you can feel if you press your fingers upon the temple while moving the lower jaw as in eating. This cushion of muscle is of great use in breaking the force of a blow received in that quarter. Other points might be specified where there is arrangement for special protection, but those to which I have alluded will suffice.

279. The cranium not only contains and protects the brain, but it at the same time serves various other purposes, and protects other important organs. The tender and delicate eye has there a bony socket with jutting prominences all around it, to guard it against violence. The exceedingly minute and complicated apparatus of the hearing is also carefully protected by

the skull, and the most important part of it is furnished with winding and intricate apartments, halls of audience, in that part of the temporal bone which is so hard, that it is called the *petrous* or rock-like bone. To the bones of the cranium are attached in various ways, the fourteen bones of the face. All these, with the exception of the lower jaw, are immovable. The two principal of them are the upper jaw bone, and the cheek bone. The former makes with its mate of the other side the forward portion of the roof of the mouth, the palate bones making its rear portion; and it furnishes the sockets for the teeth. It also at its upper part makes nearly the whole of the floor of the orbit of the eye. The cheek-bone forms the outer lateral part of the socket of the eye, and sending back a process or projection to unite with one from the temporal bone, *c*, Fig. 87, forms the *zygoma* or arch, inside of which the temporal muscle passes down to be fastened to the lower jaw. The bones of the nose make quite a complicated series of cavities, for the purpose of presenting, in the mucous membrane, which lines them, a large surface, over which the nerve of smell is expanded. A representation of these cavities is given in Fig. 89; in which *a* is the mouth; *b*, the opening into the nostril; *d*, a part of the base of the skull; *c*, the communication of the nostril with the back of the throat; *e*, the curtain of the palate; *l*, the frontal sinus; *m*, another large sinus; *g*, *i*, *h*, spongy bones projecting into the cavity of the nostril. There is a large sinus, that is not seen in this figure, which lies over the teeth in the jaw-bone. The different sinuses are lined with the mucous membrane extending into them from the nose. These, with the spongy bones make a very large extent of surface in the cavities devoted to the sense of smell. The branches of the nerves of smell enter these cavities, to be distributed over thin walls, through many small openings in a bone in the roof of the nose, giving it a sieve-like appearance.

FIG. 89.



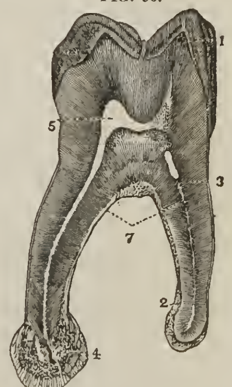
INNER BONES OF THE NOSE.

280. The lower jaw is a bone shaped something like a horse shoe, with its ends turned considerably upward. It has two

smooth projecting surfaces which articulate with two corresponding shallow cavities in the temporal bone. Its prominence at the lower part in front, the chin, is peculiar to man, there being no such prominence in any other animal. The lower jaw has sockets for the teeth, and it is so constructed, and is so arranged with muscles, that these teeth can be brought to bear against the teeth of the upper jaw in cutting and grinding motions.

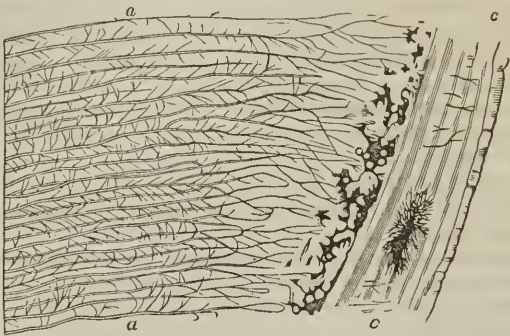
281. The teeth are very nearly like the bones in their structure, but they differ from them in some particulars which it will be interesting to notice. Every tooth has in it three distinct structures, which differ in hardness, for reasons which will appear clear to you as I proceed. The *dentine* or ivory constitutes the body both of the tooth and of its fangs. In the body of the tooth there is a coating of that very hard substance, the enamel, over the whole surface of the ivory. This is thickest over the top of the tooth, and grows thinner on the sides till it is entirely gone where the gum begins. The ivory in the fangs has a coating of a very different character, called the *cementum.* It is not hard like the enamel. This arrangement is represented in Fig. 90. This is a tooth with two fangs or roots; 1, is the enamel; 3, the dentine or ivory: 2, and 7, the cementum; 4, an unnatural enlargement of the cementum, making an excrescence; 5, the cavity of the tooth supplied with bloodvessels and nerves which come through the channels that you see running up the middle of each fang. This cavity is analogous to that which is found in the shafts of the long bones as seen in Fig. 83. The ivory and the cementum are seen by the microscope to be very different textures. The ivory is traversed by innumerable branching tubes running from within outward towards the cementum, as represented in Fig. 91. This is a section of a small portion of the dentine and cementum in the fang of a tooth, very much magnified, *a*, *a*, being the dentine, and *c*, *c*, the cementum, evidently a different structure. The structure of the enamel as exhibited

FIG. 90.



Vertical
SECTION OF A TOOTH.

FIG. 91.



by the microscope is represented in Fig. 66 and 67, in the chapter on Cell-Life. I have been thus particular in the description of the parts of a tooth, that you may see how compound even so apparently simple a part of the body is. The three different structures in it are built by cells, and the cells of each part select from the blood such constituents as are needed for their purpose.

282. A tooth differs from a common bone in one important particular—when once formed it is never altered in its size. A bone grows with the growth of other parts of the body; but a tooth, when it first protrudes through the gum is as large as it ever will be. The reason of this is, that so hard a substance as enamel can not be made changeable as bone is. Its hardness is inconsistent with any thing like circulation in it, and without circulation there can be no change. If the enamel were not needed, and the teeth could be composed only of dentine, they could grow as other bones do. And if they could grow, one set of teeth might be made to answer the purpose. As it is, the second set are needed, because as the jaws grow, the first set are neither large enough in proportion to the size of the jaws, nor numerous enough to fill up the whole space. If the first set were to be the only set, when the jaws became of their full size, the teeth would be altogether too small, and would be quite separated from each other. Twenty small teeth (the number of the first set) in the jaws of an adult, in place of the thirty-two large teeth of the second set, would present a very odd appearance, besides being incapable of doing the service required of them.

Under the lower jaw is a little bone, called from its resemblance to the Greek letter *v*, the *hyoid* or u-like bone. Its round end is towards the root of the tongue, and its two ends reach backward towards the spine. The larynx is suspended from it as from a frame, and the muscles that draw up this bone, draw up the larynx with it. It is one of the few bones in the body that are not directly connected with any other bone. The *patella*, or kneepan, is one of these bones. The four little bones in the ear, of which I shall speak particularly when I come to treat of the sense of hearing, are not connected with any other bone.

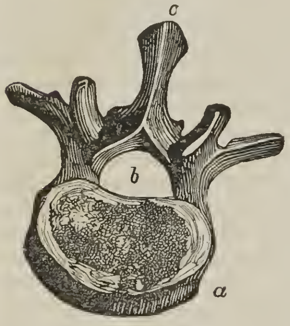
283. I pass now to the bones of the trunk of the body. I shall speak first of the spinal column, or the backbone, as it is called in common language, as if it were all one bone. In some respects it does act as one bone, although it is made up of twenty-four distinct bones. It is the great pillar of the body. As such, it has the head resting on its top, and it furnishes support for the walls of the chest, and for the muscles which make up the most of the walls of the abdomen. To it also are fastened, as you have seen in the chapter on Digestion, the mass of intestines in the abdomen, and indeed to some extent all the viscera both of the abdomen and the thorax. Sustaining, therefore, as it does so much weight in so many ways, it stands firmly planted on its great pedestal, the strong broad bone of the pelvis, the sacrum. And this pedestal is supported, as I have before said, after the manner of a keystone, between the lighter spreading bones of the pelvis on either side. But while the spinal column acts as a strong and firmly supported pillar, it is necessary that it should be *flexible* for the different motions of the body. It is therefore composed of twenty-four bones called the *vertebræ*, so that, as in any considerable motion of the column as a whole, there is but little motion between any two of them, the motion does not interfere with its office as a firm pillar. It is most free in its uppermost part, the neck; it is considerable in its lower part, the small of the back; and it is least of all in that part to which the ribs are joined. You readily see the reasons for this difference in motion in different parts of the column. For the varied motions of the head there is need of a free movement between the vertebræ. Then for the twisting and turning motions of the body, you have the free movement between them at the lower part of the column, which is easily provided for there, because there are attached to that portion of it nothing but parts that are pliable. It is not

so with that portion of it that forms the supporting pillar of the framework of the chest. There is little motion here between the vertebræ, because the joining of the ribs to the column forbids it.

But besides serving as a firm pillar, and as a flexible chain, the spinal column also forms a canal or tube in which the spinal marrow, one of the most delicate and important organs in the body, is securely lodged. This canal extends through its whole length, and from the spinal marrow included in it there pass out the nerves to go to all parts of the body.

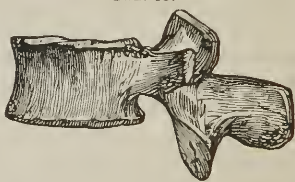
284. Having thus presented a general view of the spinal column, I will now give a particular description of the form and arrangements of the bones of which it is composed, so that you may understand how the various objects of this wonderful structure are secured. In Fig. 92 you see a representation of

FIG. 92.



A VERTEBRA.

FIG. 93.



A SIDE VIEW OF A VERTEBRA.

one of the vertebræ; *a*, being the *body* of the bone; *b*, the hole which forms this vertebra's part of the canal for the spinal marrow; and *c*, the spinous process. It is these spinous processes that make the row of projecting points seen down the length of the back. There are six other processes, only four of which you can see in the figure. Four of these processes serve to lock the vertebra with its two adjoining ones above and below, which they do so strongly, that there can be no dislocation of them without a fracture. Fig. 93 gives a side view of a vertebra. Strong ligaments bind these bones together, and there are very numerous muscles attached to the processes, so

that this jagged column of bones is very thoroughly enveloped in softer substances.

FIG. 94.

SPINAL COLUMN.

285. In Fig. 94. you see the whole spinal column with the sacrum on which it stands. It is laid open by a vertical section dividing it into two halves, so as to show the manner in which the bones form the tube that contains the spinal marrow. The darkly shaded strip through the length of the figure represents this tube. It extends, you see, down beyond the limits of the column itself through the sacrum. It is bounded in front by the bodies of the vertebræ represented as sawn through from front to rear, and by the spinous processes behind also sawn in the same way. In this canal you see there is a row of little openings, arranged just behind the bodies of the vertebræ. Through these openings, each of which is between two of the vertebræ, the nerves go out from the spinal marrow. The arrangement is such, that the nerves are very securely guarded against the hazard of pressure in the movements of the vertebræ upon each other. You see also that there are spaces between the bodies of all the vertebræ. These are filled with cartilages, which vary in thickness in different parts of the column, from one quarter even to three quarters of an inch, being thickest in the lower part of the back, where the backward and forward motion of the vertebræ upon each other is the greatest. Each cartilage is firmly fastened to the two vertebræ, between which they are situated, by the rough surface of the body of the bone which you see represented in Fig. 92. This arrangement of cartilages is an important provision for the motion of the spinal column. It contributes greatly to its flexibility. When you stoop forward, all of the cartilages are compressed, and when you rise up they return to their usual size by their elasticity. And besides this, they serve to diminish any shock which

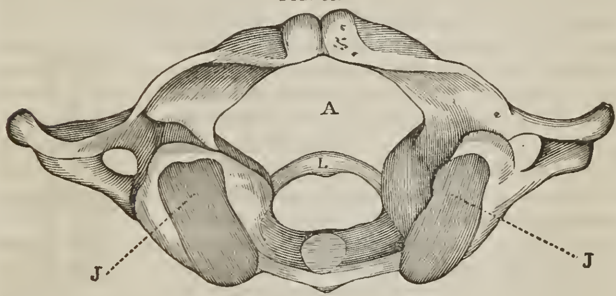
might otherwise be transmitted through the column of bones to the head with too great force. There is another guard against the injurious transmission of shocks to the brain, in the *shape* of the spinal column, the twenty-four bones being arranged, not in a straight line, but in a double curve. The vibration, communicated upward through the spinal column, is thus not only lessened by the elasticity of the cartilages, but is also distributed in different directions by the curved arrangement of the bones. If the column had been made straight, the head would have been subject to frequent jars in the movements of the body, which would be disagreeable and often injurious.

286. You have thus seen how three different objects, apparently incompatible with each other, are accomplished in the arrangement of the spinal column. To put twenty-four bones together in such a way, that they shall form a strong firm pillar for the whole frame, and yet they shall make a column or chain flexible enough for the various motions of the trunk of the body, and at the same time provide in this column a secure canal for the rod of nervous matter which moves all the muscles of the body, is to produce a piece of mechanism which far transcends any thing that has ever been contrived by the ingenuity of man.

287. There remains to be noticed one especial contrivance in the spinal column. It is at its summit, and it is for the purpose of providing for the free motions of the head in various directions, and at the same time securing the spinal marrow at that part from all hazard of pressure from these motions. These two objects are accomplished in this way. The head in moving backward and forward rocks on two smooth surfaces on the first vertebra. But when the head moves to the right and left, this first vertebra moves along with the head on the second vertebra. And there is a tooth-like process that projects up from the second vertebra inside of the first, around which this rotary motion is performed. In Fig. 95 is represented the first vertebra. J. J. are the two surfaces on which the head rests, and rocks backward and forward. A is the opening for the spinal marrow. L is the strong ligament which confines the tooth-like process that projects upward from the second vertebra. In Fig. 96 is the second vertebra. P is the tooth-like process, around which the first vertebra rotates, carrying the skull with it. You see it is smaller at its root than at its top. This smaller part is bound firmly by the ligament in the first

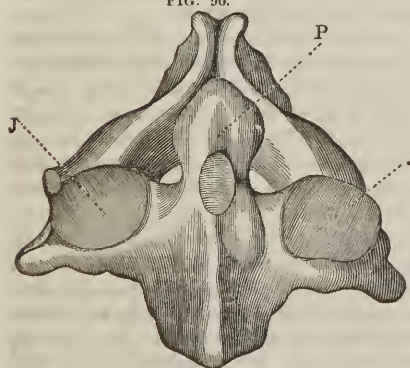
vertebra. It is shaped thus to prevent its slipping out from the ligament. J, J, are the two surfaces on which the first vertebra moves as it rotates around the tooth-like process. Fig. 97 shows the two bones together, the tooth-like process being confined in the ring of the upper bone. Special pains are taken to make this arrangement secure, that the process may not be in danger of pressing upon the spinal marrow at this important point. It is thus that the lateral rotary motion of the head and the forward and backward motion are secured by two joints, just as is done in the mounting of a telescope. The difference between the two cases is, that in the mounting of the telescope there are no difficulties to overcome, while in arranging the

FIG. 95.



FIRST VERTEBRA.

FIG. 96.



SECOND VERTEBRA.

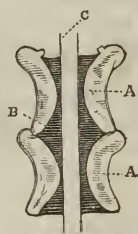
FIG. 97.

First and Second
VERTEBRÆ TOGETHER.

mounting of the head, as we may term it, a peculiar contrivance and a nice adjustment are needed to prevent injury of a very important organ. It is a wonderful contrivance, by which so much and so varied motion can be effected in the very walls that contain the soft and delicate spinal marrow, without injuring it. You will fully appreciate this, if you observe the extent and variety of the motions of the head and neck, executed chiefly with the two bones that I have described.

288. In the neck of birds there is a contrivance of a different character, for the arrangement which answers for the motions required by man, obviously could not secure the very free motions which the bird executes with its neck. As the bird bends its neck at such abrupt angles in all directions, a peculiar arrangement of the vertebræ is necessary, to prevent the spinal marrow from being pressed upon. The arrangement is a simple, but effectual one. I can make this plain to you by the rough diagram in Fig. 98. A, A, are two of the vertebræ of the neck laid open. B is the spinal canal, and C is the spinal marrow. You observe that each vertebra is larger at its ends than in the middle, allowing at the joinings of the bones, where the motion is, a considerable space between the bone and the spinal cord. Now if each of these bones were of equal size throughout, and the spinal marrow filled up the canal, you can readily see that when any two of these were much bent upon each other, there would be pressure upon the spinal cord; and pressure would produce palsy, and often destroy life. But with the simple arrangement above described, free motion, almost to a right-angle in some directions, can be executed without pressing on the cord. And besides this, you can see that the cord by this arrangement will not be bent at an angle, as the vertebræ are, but in a curve, for the spaces in the spinal canal at the joinings allow of a lateral movement of the spinal marrow at these points.

FIG. 98.



SPINAL COLUMN in Birds.

289. It would be interesting to consider in full the variations in the spinal column in different classes of animals. But I will only allude to a few of them. In quadrupeds, as they have their heads suspended, instead of being supported, as in man, upon a column of bones, the spinous processes in the neck are very large, and project much, for the attachment of strong muscles which hold up the head and move it. There is also

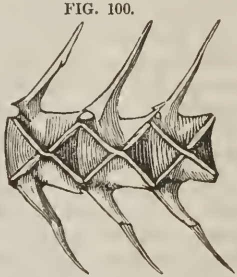
attached to these processes, a very stout fibrous ligament, commonly called the *paxy-waxy*, to assist in sustaining the head. In fishes the spinal column is so arranged as to give it a great flexibility. In Fig. 99 is represented one of the vertebræ of a fish. If you compare it with a human vertebra, as seen in Fig. 92, you will see that it differs very widely from it. It has no transverse or side processes. While the human vertebra has one *spinous* process that projects behind, this has two *f*, *f*, one in front and one in the rear, or rather, according to the usual position of the fish, one above and one below. The body of the vertebra has a cup-like cavity on each side towards its neighboring vertebra. When, therefore, two of these vertebræ are joined together, their two cup-like cavities make one cavity of the shape of a double cone, as seen in Fig. 100.

FIG. 99.

VERTEBRA of a Fish.

This is a representation of a section of a portion of the spine of a fish. The division is made so as to cut the vertebræ into two halves, and thus show these cavities. Each one of these contains a sac which is filled with a gelatinous fluid. This arrangement, which secures very great flexibility of the spinal column, you can examine at any time when you have fish on the table. The long spinous processes make the broad frame-work of the animal, to which its muscles are attached. In reptiles there is still greater flexibility of the spine than in fishes. This is secured in two ways, by the great number of the vertebræ, and by a peculiar arrangement of them. There are three hundred and four vertebræ in the boa constrictor, over three hundred in the common ringed snake, and over two hundred in the rattle-snake. The articulations of the vertebræ in reptiles are with a ball and socket arrangement. The forward part of each vertebra has a deep cup-like depression, in which plays a round smooth ball from the back part of the next vertebra. And as these joints are firmly bound together by ligaments, the spinal column is very strong as well as flexible. In the gracefully flexible neck of the

FIG. 100.



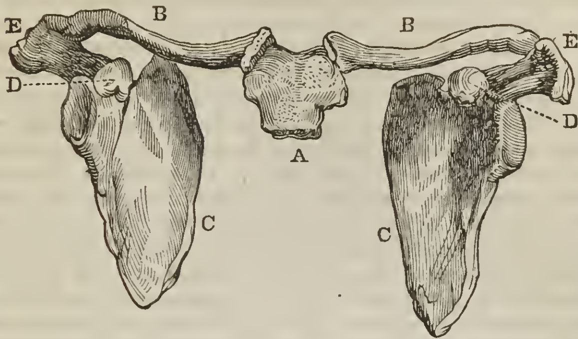
SPINAL COLUMN OF A FISH.

giraffe we have the same ball and socket articulations of the vertebræ.

290. The framework of the chest I have already described sufficiently in the chapter on Respiration. The breastbone, which is flat and of simple form in man, is much larger and less simple in its form in some animals. In birds it is not only broader, but it has a keel-shaped projection for the attachment of the large muscles used in flight. . The *clavicle*, *g*, Fig. 86 (so called from its resemblance to a key,) and commonly called the collar-bone, is attached at one end to the top of the breastbone, and at the other unites with a process of the *scapula*, or shoulder-blade at the top of the shoulder joint. It is a prop to the shoulder, pressing it outward ; and accordingly it is large in those animals, the movements of whose superior extremities tend to bring the shoulders towards each other, while it is very slender, or absent even, in those the tendency of whose movements is to keep the shoulders apart. Thus in birds the drawing down of the wings by the strong muscles would bring the shoulders towards each other, were this not prevented by stout clavicles. Sometimes a second bone is added for the same purpose. But in the horse and other similar animals, the pressure of the body downwards between the shoulders tends to separate them, and here we find the clavicle deficient because it is not needed. The *scapula*, or shoulder blade is a thin bone with a stout raised spine or ridge running across it, and ending in forming the top of the shoulder joint. It is situated differently from any other bone in the body. It is imbedded in muscles and has a very free motion. Its design is to give freedom of motion to the arm. It is directly connected with the skeleton only by its union with the clavicle. In Fig. 101 you see the arrangement of the clavicle, scapula, and breastbone. C, C, are the scapulæ or shoulder-blades. A, is the upper part of the breastbone. B, B, are the clavicles fastened to the breastbone at one end, and to the shoulder-blade at the other end at E, which is a process of the shoulder-blade, making the projecting top of the shoulder-joint. D, is another process of the shoulder which serves for the attachment of muscles and ligaments. It is called the *coracoid* process, from its resemblance to the beak of a crow.

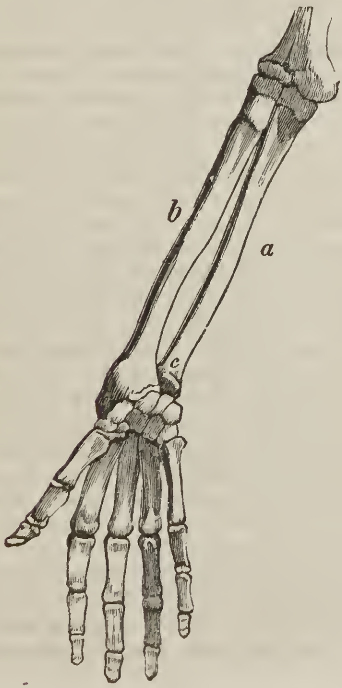
291. The upper extremity is divided into three parts, the arm, the forearm, and the hand. The arm has but one long bone, the *humerus*, *i*, Fig. 86. This has a round head which moves in a shallow cup formed by the shoulder-blade. The

FIG. 101.



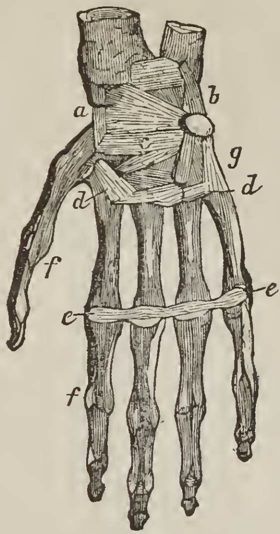
THE COLLAR-BONES AND THE SHOULDER-BLADES.

FIG. 102.



shallowness of the socket is the cause of the frequent dislocation of the shoulder. But if there were a deep socket like that in which the head of the thigh-bone is, the arm could not have any thing like the freeness of motion that it now has. Such an arrangement would involve too much of a sacrifice of necessary uses for the sake of security. At its lower part the humerus makes a hinge joint with the forearm. The forearm has two bones, the *radius*, *b*, Fig. 102, and the *ulna*, *a*. The particular arrangement of these two bones is worthy of notice. The hinge-like motion of the forearm upon the arm is performed by the *ulna* alone. This bone has a beak-like process, which works over a smooth round surface at the end of the humerus. It is the outside of this process which you feel at the point of the elbow. The other bone, the *radius*, has nothing to do with this motion. This only rolls on the ulna in the rotary motions of the forearm. But at the other end of these bones, at the wrist, the arrangement is reversed. Here, it is the radius on which the hand moves in a hinge-like manner, while the ulna at *c* rolls on the radius, as the radius does on the ulna at the elbow. You can readily see that as the radius rolls on the ulna at the elbow, and the ulna on the radius at the wrist, a very free rotary motion of the forearm is provided for. The combination of this motion with the motions at the wrist, the elbow, and the shoulder, secure that almost endless variety of movement, which is so striking a peculiarity of the upper extremity, as compared with the lower. The hand is divided into three parts, the *carpus*, *p*, Fig. 86, composed of eight small bones, the *metacarpus*, *q*, composed of bones which are like the bones of the *fingers*, *r*. The eight bones of the carpus are firmly packed together, but they have a slight motion upon each other, and this, together with the motion of the metacarpal bones, makes the hand a more easy, light, and springy instrument than it would be, if these bones were all consolidated into one. The metacarpal bones are the framework of the flat part of the hand, and to them are joined the first row of the bones of the fingers. The metacarpal bone of the thumb has a very free motion upon the carpus, differing in this respect altogether from the metacarpal bones in the body of the hand. The bones in the wrist and hand are bound together by very strong ligaments. Those which are seen in the palm of the hand are represented in Fig. 103. Those which you see at *a*, *b*, and *c* bind the small bones of the wrist together, and also tie them strongly to the bones of the forearm, the ends of which you see

FIG. 103.



in the Figure. The bone at *b*, to which so many of these ligaments are attached, is the prominent bone which you feel at the beginning of the palm of the hand on the side towards the body. The ligament *g* connects this bone with the metacarpal bone of the little finger. At *d*, *d*, are ligaments which running across the hand bind the metacarpal bones together at their beginning. At *e*, *e*, are similar ligaments where the bones of the fingers join them. The bones of the fingers and thumb are strongly held together by lateral ligaments, as seen at *f*, *f*. The various ligaments of the wrist and hand permit a slight motion between the bones; and thus the hand has freedom and ease in its motions while it is also a very strong and firm instrument.

292. The lower extremities have some resemblance to the upper in their structure and arrangement, but they differ from them in some important respects. Here firmness is the chief object, while freedom of motion is the great thing to be secured in the structure of the upper extremities. The lower extremi-

ties are chiefly for locomotion, but the upper are fitted for a variety of purposes. The body is supported upon the lower extremities, and, therefore, the thigh-bones have sockets in the broad flaring bones of the pelvis *m* and *l*, Fig. 86. In Fig. 104 is represented a rear view of the thigh-bone. Its head, *a*, is round, and fits into a deep socket in the *pelvis.* At *b* is a depression in which one end of a stout short ligament is fastened, its other end being attached to the bottom of the socket. At *c* is the neck of the bone; at *d* and *e* are two projections to which are attached large muscles to move the limb. Along the shaft of the bone, *g*, there is a rough ridge, *h*, to which muscles are fastened; *i* and *k* are two smooth surfaces for articulation with the leg below. At *t*, Fig. 86 is the bone called the *patella* or kneepan, which answers as a defense to the joint, and at the same time affords a mechanical advantage to the muscles which throw the leg forward. These muscles are fastened to the upper part of the patella, and then a connection is formed by a strong tendon between its lower part and the large bone of the leg. You see at once that the leg can be thrown forward with more force by this arrangement, than it could be if the tendon of the muscles passed over the front of the joint without any patella. I shall refer to this again in the Chapter on the Muscles. The leg, like the forearm, has two bones, *v* and *u*, Fig. 86; but unlike them they are constructed and arranged for strength, and not for freedom of motion. The foot, like the hand, is divided into three parts. The *tarsus*, *a*, Fig. 105, is that part of the foot which extends from the heel to the middle of the foot. It is composed of seven bones, the largest of which makes the body of the heel. The *metatarsus*, *b*, has five long bones reaching

FIG. 104.

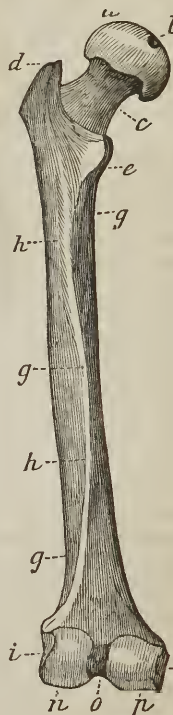
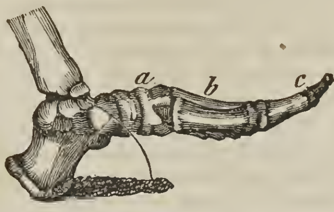


FIG. 105.



from the tarsus to the toes. The toes, *c*, have fourteen bones. The object of having so many bones in the body of the foot is to give a certain springiness to it, which guards against shocks, and facilitates motion. Its arched form also tends to secure the same object. In every movement of the foot there is a slight motion between all these bones. Thus in walking, when the foot first touches the ground, it does so at the heel, as represented in Fig. 105. Then as the body moves forward, the fore-part of the foot is brought down, the weight of the body at length pressing upon the ground at the ball of the foot, *b*. In executing this movement, elasticity is given to the tread of the foot by the very slight motion which occurs between these many bones. If the body of the foot were all one bone it would manifestly be a very stiff and awkward affair, and ease and grace in walking would be an impossibility. With such a foot we should not walk much better than one does with a wooden leg.

FIG. 106.

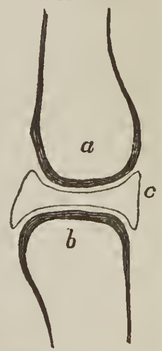


DIAGRAM
showing the lining of a joint.

293. Before leaving the subject of the bones, I will call your attention to the provision which is made for the easy movement of their joints. The ends of the bones are tipped with cartilage, so as to afford a firm but smooth surface for the motion of the one bone upon the other. Besides this provision, the ends of every two bones that move upon each other are lined with a membrane, so arranged as to make a blind sac. This is illustrated in Fig. 106, in which *a* and *b* are the ends of two bones, the sac, *c*, lying between them represented here as detached from the bone, in order that the arrangement may be clear to you. It is as if a small

bladder were introduced between the two ends of the bones, and were fastened all over the surfaces that press together. The inside of this sac is kept lubricated with a bland fluid resembling the white of egg, so that the joint may work easily. This fluid is secreted by the membrane itself, and the moving machinery of the human system may therefore be said to oil its own joints. In the knee-joint, the broad surfaces of which are subjected to so much pressure, there are two flat pieces of cartilage loose in the joint, which operate like friction wheels in lessening the friction. There is a similar provision in the articulation of the lower jaw. This member does so much work in talking, and such heavy work in mastication, that each of its joints has a movable cartilage for the diminution of friction. Sometimes when the lubricating fluid is deficient, or becomes too thick, a disagreeable crackling noise is produced by these cartilages in the motions of the jaw.

CHAPTER XII.

THE MUSCLES.

294. Having described the bones, I now proceed to speak of the muscles, which move them and other parts of the frame. I have already described the structure of muscles in § 203 in the chapter on Cell-Life. Each fibril, you there saw, is a chain of cells, and it is the shortening of all these chains of cells in a muscle that produces its contraction. The action of a muscle is dependent upon the nerves. Each fibril has a nervous fibril or tubulus, (§ 232.) by which its connection with the brain or spinal marrow is established. And each fibril is in this respect probably wholly separate from every other fibril. When, therefore, the mind wills that a certain motion shall be performed, an impression (§ 232) is sent to each fibril of every muscle engaged in that motion, through the tubulus devoted to that fibril. When the action is a very compound one, calling into operation many muscles, a multitude of these impressions are communicated through a multitude of distinct channels or tubuli. The individual is not at all conscious of the compound nature of muscular action, and he knows nothing of the muscles

which produce any particular movement, unless he has studied anatomy and physiology. He wills the movement to take place, and at once the requisite impressions are sent along the appropriate channels or tubuli to their destination. These impressions must differ in degree or intensity in producing different amounts of motion; and they must differ in some cases in different parts of the same muscle, as some fibres are put in motion while others are not, or as some act with more force than others. I will not dwell here on this point, as I shall recur to it in another part of this chapter, when I come to speak of the compound character, and the varieties of motion.

295. Muscles commonly end in tendons, which, as they are white and shining, are quite in contrast with the red muscular fibres. The tendons have in themselves no power of contraction, but are mere passive cords. They have the same relation to the muscles, that ropes have to the men that pull them. They are of various shapes, according to circumstances. Long and slender tendons may be seen on the back of the hand in thin persons, the muscles that pull them being in the full arm above. The tendons are not bounded by a distinct line where they join the muscles, but tendinous and muscular fibres intertwine, so that they appear to run insensibly into each other. Tendinous fibres also mingle in the same way with the fibres of bone, making so strong an union, that a great force exerted in pulling on the tendon will sooner effect a rupture of the tendon or the bone, than a separation of the connection between them. The tendons are very strong, being made of very condensed fibrous substance. The tendon of a muscle is, therefore, much smaller than the muscle itself. This is a circumstance of much importance in the arrangement of the moving apparatus of our frames. The bulky muscles and the slender tendons, are so arranged, for example, in the limbs, as to give them both freedom of motion and beauty of form. The muscles that move the fingers help to make up the full part of the arm, while their slender tendons occupy but little space as they play over the bones of the wrist. If there were no tendons, and the muscles were extended to the parts which they move, the hand would be a large cumbrous mass, instead of the light and agile thing that it is now. For the muscles would of necessity be continued of their full size, and, therefore, the bones would of course be very large in order to afford an attachment to the muscles.

296. In the action of the muscles upon the bones, we have

examples of the three kinds of levers treated of in natural philosophy. Some of these I will now notice. The first kind of lever has the fulcrum between the weight and the power, as represented in Fig. 107. F is the fulcrum, W the weight, and

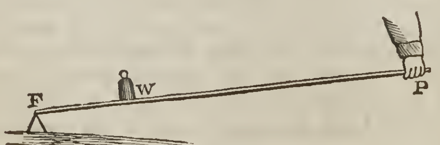
FIG. 107.

FIRST KIND OF LEVER.

P the power. You have examples of this lever in the common pump handle, the beam of a pair of scales, the crowbar, as commonly used, scissors, &c. You have an example of this form of lever in the human body, in the action of the muscles in moving the head back and forth on the top of the spinal column. In this case, when the head is moved forward, the top of the spine is the fulcrum, the weight to be moved is the back of the head, and the power is the contraction of the muscles that bow the head forward. When the head is bent backward, the power is the contraction of the muscles behind, and the weight is the front part of the head. The muscles that move the head backward are stronger than those that move it forward. It is necessary that it should be so, for there is more of the head in front of the point of support or fulcrum than there is behind it. Hence, when sleep relaxes the muscles, if we are sitting up the head falls forward.

297. In the second kind of lever the weight is between the fulcrum and the power, as represented in Fig. 108. The common wheelbarrow is an example of this form of lever. You have an example of it in the body in the raising of the heel

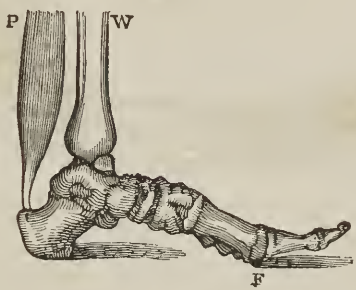
FIG. 108.



SECOND KIND OF LEVER.

from the ground in walking. In doing this the weight to be raised is the whole body, the foot being the lever, and the forward part of the foot being the fulcrum. This will be made clear by Fig. 109. W is the large bone of the leg sustaining

FIG. 109.



the weight of the body; F, is the fulcrum, the forward part of the foot that presses on the ground as the heel is raised; and P, is the large muscle in the calf of the leg, the power that raises the heel, the end of the lever.

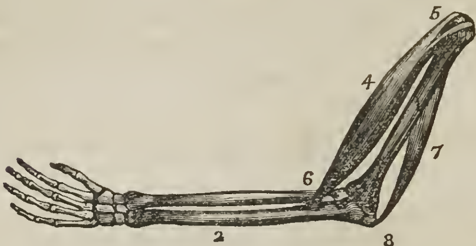
298. In the third form of lever the power is between the weight and the fulcrum. A common example of this is seen in the raising of a ladder. The fixed foot of the ladder is the fulcrum, the ladder itself is the weight, and the power is applied as far from the fulcrum as it can be. Fig. 110, represents

FIG. 110.

THIRD KIND OF LEVER.

a lever of this kind. This form of lever is more frequently used than the other forms in the human body. We have an example of it in bending the forearm upon the arm as seen in Fig. 111, in which 1 is the bone of the arm; 2, the bones of the forearm; 4, the muscle which bends the forearm upon the arm; 5, its double headed attachment above; and 6, its at-

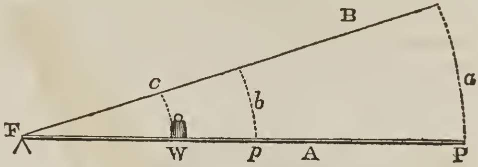
FIG. 111.



tachment to the ulna, the chief bone of the forearm. In this case the fulcrum is at 8, the joint of the elbow, the weight is the hand with whatever it holds, and the power is applied at the point where the tendon is fastened to the ulna, that is, as in the case of the ladder, between the fulcrum and the weight. The muscle which straightens the forearm upon the arm is represented at 7. I shall remark upon this in another connection.

299. In the management of the three kinds of levers there are two different objects aimed at under different circumstances. One object is to move a great weight with a small power. Here quickness is not aimed at, but the weight is moved slowly. The other object is to move the weight quickly, an object inconsistent with the moving of any very heavy weight. When the object is to move a heavy weight slowly, the lever is so managed as to get a good purchase, as it is expressed. Thus in the case of the lever of the second kind, Fig. 108, if the weight be a heavy one, the power is commonly applied at some distance from the weight. The nearer the power is to the weight, the greater must it be to move the weight. The smaller the power, the further must it be from the weight in order to raise it. But though a small power if at a distance from the weight answers to raise it, yet in this case the power must move through a considerable space to move the weight but little; while to raise the weight to the same height, a power nearer to it passes through but little space. This will be made clear to you by Fig. 112. F is the fulcrum, and W the weight. If the lever, A, be raised to the line, B, the dotted lines will show the different spaces which the power passes through, according to its distance from the weight. If the power be at P,

FIG. 112.

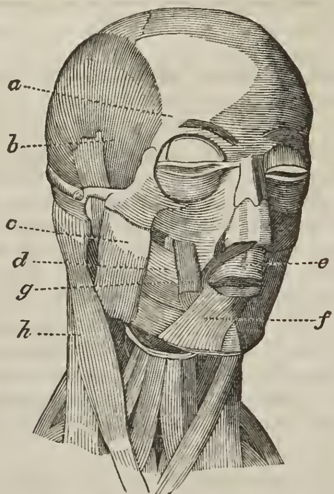


it passes through the space indicated by the dotted line *a* in moving the weight W to *c*. But if it be at *p*, it passes through a much shorter space, *b*, in raising the weight to the same height. The more important, therefore, in this form of lever quickness of movement is, the nearer to the weight is the power applied. Let us look at the application of these principles to the example of this kind of lever, which I cited from the human body, represented in Fig. 109, the raising of the weight of the body on the foot in walking. The power is here applied quite near to the weight, for quickness in raising the heel in walking and running is of great importance. By having the heel project farther behind, the muscle could be attached farther from the weight, and thus act with more power. But there would in this case be a sacrifice of quickness of movement, and besides this, the lengthened heel would present a very awkward and ugly appearance.

300. But it is in examples of levers of the *third* kind that we find these principles best illustrated. This form of lever is much more often used in the mechanism of the muscles than the other forms. I refer you to the example given of this lever in the action of the biceps muscle in bending the forearm, as shown in Fig. 111. In this case it is of much more importance to move small weights quickly, than to move heavy ones slowly. Therefore the power is applied quite near to the fulcrum. The tendon of the biceps, as you see, is fastened to the main bone of the forearm near the fulcrum, the elbow. You can readily see that the point where the power is applied would pass through but a little space, in moving a weight through a considerable one. The lower jaw, in its upward motion, is a lever of the same kind. In this case, force rather than quickness is required in breaking and grinding the food. Here, therefore, the power, the action of the muscle, is applied farther from the fulcrum than in the case of the biceps muscle of the arm,

and nearer to the weight to be moved, or the point where the resistance is which is to be overcome. It is applied also in a different direction, a point which I shall however speak of in another connection. The muscles which move the lower jaw upward can be seen in Fig. 113. One is the large spreading

FIG. 113.



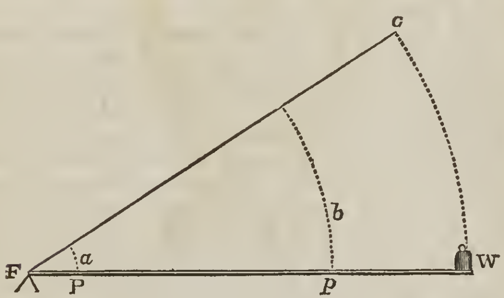
MUSCLES OF FACE AND NECK.

muscle *b*, the swelling of which, in its contraction, we can feel, if we place the fingers on the temple while moving the lower jaw upward. The other is the short strong muscle *c*, the front edge of which is so far forward, that one-third at least of the lower jaw-bone is embraced by this muscle. Now, if you compare this bone as a lever with the forearm as acted upon by the biceps, you will at once see that the power is applied much nearer to the weight, or the resistance to be overcome, in the case of the jaw, than in the case of the arm. It is so even when the resistance to be overcome is at the front teeth; and it is much more so when the resistance is at the back part of the mouth, as when we are grinding our food. Here, indeed, a portion of the muscular force is brought to bear upon the resistance in a direct line. It is not merely because the back teeth are

stronger than the front ones, but also because the power is nearer the resistance, that we can crack a nut more easily with the back, than we can with the front teeth.

301. It is clear that the biceps muscle acts, as it is expressed, at a mechanical disadvantage, if we regard mere power or force, and leave out of view quickness of motion. If it were inserted further down on the forearm, nearer the hand, it could raise much greater weights than it now can. And the same can be said of most of the other muscles of the body. But force is sacrificed for the sake of quickness in most cases, because the latter is more important. In the few cases in which force is more important, as in the case of the lower jaw just cited, the reverse arrangement is provided. The gain in quickness in the arrangement of the biceps muscle can be illustrated on Fig. 114.

FIG. 114.

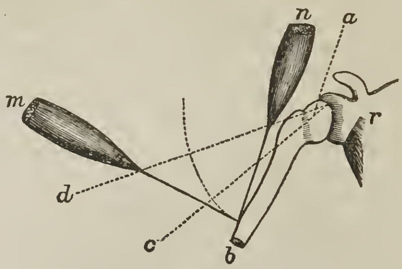


F being the fulcrum, the power in raising the weight, W, to *c*, if acting at P, passes through the space indicated by the dotted line *a*. But if it act at *p*, it will pass through all the space *b*, and of course raise the weight more slowly than when acting at P.

302. Most of the muscles work at a mechanical disadvantage in another way. I refer to the direction in which the muscle acts on the bone to be moved. This is seldom at right angles, and therefore a considerable part of the force exerted is lost. This can be made clear to you by Fig. 115. Let *b* represent the bone of the arm, and *r* its fulcrum, or point of support in the shoulder. You readily see that if the bone be acted on by a muscle, *m*, at right-angles to it, it will require less force to move it to a given point than would be required if the same muscle were placed in the position represented by *n*. For the

When loss in power, gain in quickness.

FIG. 115.



muscle *n*, acting obliquely on the bone would expend a part of its force in pressing the end of the bone upward against the socket of the joint at *r*.

303. But in this case also, what is lost in power is gained in quickness of movement. This can be shown on the figure. We will suppose that the muscle contracts or shortens itself the half of the length of the tendon. If the muscle were placed as at *m*, the bone would be carried to the line *a*, *c*. But if the muscle be placed as at *n*, the same degree of contraction would raise the bone to the line *a*, *d*, the point of the bone where the tendon of the muscle is attached moving in the curved line as marked. The resistance to be overcome, of course, requires much more power for the obliquely placed muscle, *n*, to raise the bone to the line *a*, *d*, than for the muscle *m* to raise it to *a*, *c*; and therefore a much larger muscle is needed than there would be if it acted at right-angles to the bone as at *m*. And the muscle which raises the arm at the shoulder, acting as it does at so great disadvantage, is a very large muscle. The muscle, *n*, in the figure represents only the line of its action, and not at all its shape. If you observe the various motions of the arm in which this muscle has a part, you will appreciate the necessity of so arranging it as to secure quickness of movement. This was the chief object to be aimed at in its arrangement; and the second and less important object, power, is secured, so far as it is needed, by simply making the muscle a large one.

304. The mechanical disadvantage, which I have noticed as resulting from the oblique action of the muscles, is in part obviated by a very simple contrivance. It is done by making the

tendon of the muscle work over an enlargement of the bones at the joints. The operation of this contrivance can be made clear by Figs. 116 and 117. Let *r* and *o* (Fig. 116) be the two bones of a joint, and let the muscle *m* be attached to the bone *o* at *i*. As it contracts, almost all its force will be spent in drawing the bone *o* upward against the bone *r*, because it acts almost entirely in a line with the bones. But let the ends of the bones be enlarged as in Fig. 117, and you can see that the direction of the tendon of the muscle *m* is so changed where it is attached to the bone, that the muscle can now very easily make the lower bone turn upon the upper. The enlargement then of the bones at the joints, which is needed to give the requisite extent of surface for working them, answers also another good purpose in thus altering the direction of force in the muscles. In the case of the knee-joint there is an additional contrivance for making this change of direction still greater. A movable bone, the patella or kneepan, besides acting as a protection to the joint, effects also the purpose referred to. The manner in which it does this can be made plain by Fig. 118, in which *a* represents the end of the thigh-bone; *b*, the end of the large bone of the leg articulating with it; *c*, the patella; *d*, the large tendon which comes from the muscle above, and is fixed into the patella; and *e*, the tendon which goes from the patella to the large bone of the leg below. The dotted line shows how much the direction of the force of the muscle is changed by this arrangement. The movement performed by this muscle is throwing the leg and foot forward, which it is by the above arrangement of the patella enabled to do with great ease in walking, and with great force in the act of kicking.

FIG. 116.

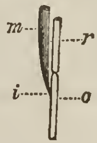


FIG. 117.

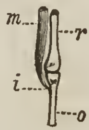
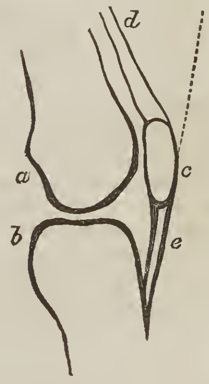


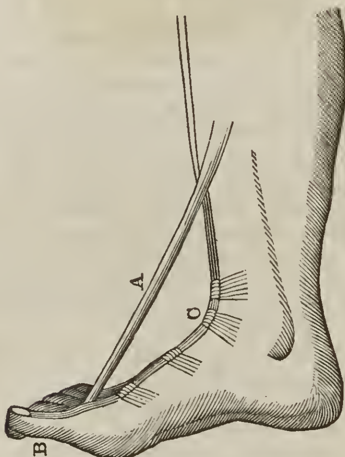
FIG. 118.



305. The pulley is used in the arrangement of the muscles, though by no means as often as the lever. It serves, whenever it is used, to give the force a different direction

from what it would otherwise have. I will cite but a few examples. At the wrist and the ankle there are broad ligaments, which bind down the tendons of the muscles, and sustain to them the relation of pullies. If it were not for these ligaments the tendons at these joints would fly out continually when the muscles are in action, making projecting cords under the skin. And if the skin were removed, the tendons would be in a position similar to that represented at A, in Fig. 119.

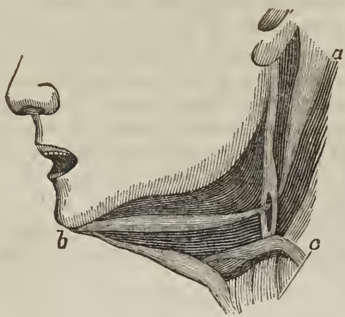
FIG. 119.



In this Figure, C is the tendon of the great toe in its position as bound down by ligaments. Now if the muscle were in the position represented by A, it is plain that it would act at a greater mechanical advantage than in the position C; but the toe would not be moved as quickly; and besides, if the tendons projected in this way, the foot would be a very cumbrous piece of machinery, compared with what it is now, with the tendons bound down around the slender ankle. So that both beauty and use are secured by the arrangement.

306. There is a beautiful application of the pulley in the case of the muscle that draws down the lower jaw, called the *digastric* muscle. It is represented in Fig. 120, in which *a* is one end of the muscle attached behind the ear, and *b* is the other end attached to the inside of the lower part of the chin.

FIG. 120.



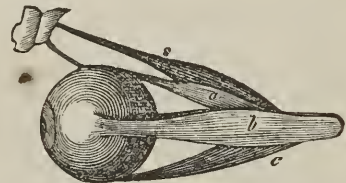
DIGASTRIC MUSCLE.

It is muscular at the two ends, and tendinous in its middle part. This middle part runs through a loop or ring in a small muscle as represented in the Figure. This little muscle is fastened above to a small process of bone under the ear, and below to the hyoid, or U-shaped bone, *c*, which is situated just above the larynx. Now when the jaw is to be drawn down, the two fleshy ends of the *digastric* muscle contract, and the middle tendinous part works in the ring provided in the little muscle. This muscle is so slender, that its loop is of itself alone hardly strong enough, as we should suppose, for the tendon of so large a muscle as the digastric to work in. And we accordingly find that there is an additional security in a strong ligament, which fastens the tendon of the digastric muscle to the hyoid bone. This ligament (which I have not represented in the figure, because it would confuse your view of the pulley-action of the parts) is sufficiently long to allow of all the freedom of motion necessary to drawing the jaw downward. You see at once that one object of this arrangement of the digastric muscle is to secure beauty of form in the neck. A muscle extending from the top of the chest to the chin in a straight direction would very effectually draw down the lower jaw, but it would be a great deformity. This is avoided by the pulley-arrangement of the digastric muscle. But this muscle answers another purpose besides drawing down the jaw. If while the jaw be held fast by muscles which draw it upward, the digastric contracts, it will draw up, as you can readily see by the Figure, the hyoid bone, *c*, and with it, of course, the larynx which is at-

tached to it. Now precisely this set of motions occurs when we swallow. The mouth is shut by the drawing up of the jaw, and then the contraction of the digastric muscle draws up the larynx, as you can perceive if you place your fingers on the larynx, or Adam's apple, as it is called, when you perform the act of swallowing. The little muscle in which the loop is, renders some assistance to the digastric in thus drawing up the hyoid bone and the larynx, as you can see by the Figure.

307. I will notice one more example of the pulley-arrangement. It is in the eye. There are six muscles that move the eye-ball. Five of them are represented in Fig. 121. There are four straight muscles, three of which are marked

FIG. 121.



a, *b*, *c*; the fourth is behind *b*, the upper edge of it only being seen in the Figure. These muscles are at their origin in the back part of the socket of the eye arranged round the optic nerve, and passing forward are attached to the sclerotic coat, the firm white coat of the eye. The two lateral muscles, *b*, and its opposite, move the eye to the one side and the other, and the two muscles, *a* and *c*, perform the up and down motions. But there are certain oblique rolling motions of the eyeball which can not be executed by these straight muscles. For these motions two muscles are provided, one of which has a pulley-arrangement, as represented in the Figure. This muscle, *s*, has a long tendon which passes through a ring in cartilage in the roof of the socket, and then turning back is fastened as you see to the upper part of the eyeball. This muscle, as stated in the chapter on the Nervous System, is under the direction of one nerve alone. It is an involuntary muscle which performs the insensible rolling motions of the eyeball, and like the other involuntary muscles of the body, is at work while we are asleep, as well as when we are awake. It is the muscle which rolls about the eye tremulously when it is open in the insensible state sometimes produced by disease.

308. Every muscle performing a motion has its opposing muscle or muscles, which perform the opposite motion. In the case of any two opposing muscles the one must be in some measure relaxed while the other is in action. Thus in alternately bending the elbow, and straightening it, there is alternate action and relaxation in the two opposite muscles 4 and 7, as represented in Fig. 111. So in moving the head back and forth the muscles in front and rear are alternately contracted and relaxed. Paley very aptly compares this to the action of two sawyers in a pit, as they move the saw back and forth. The comparison, however, is not strictly true, because the relaxing muscle is never wholly relaxed. There is indeed in every muscle some amount of contraction which is independent of action through the nerves, whether it be reflex, or produced by the will. For this reason the muscles cut off in amputation of a limb retract. So also if the muscles on one side of the face be palsied, the muscles on the other side draw the mouth to that side. The mouth is held in the middle of the face by the equal action of pairs of muscles. The head, too, is held in equilibrium in the same way. In what is called wry-neck, this *tonic* contraction, as it is sometimes termed, is greater in the muscles on one side than it is on the other. In some cases a cure can be effected only by dividing the contracted muscles. In strabismus, or squinting, one of the straight muscles of the eyeball contracts too strongly for its opposing muscle, and as in wry-neck, dividing the contracting muscle is often necessary to remedy the difficulty.

309. Most motions are not performed by single muscles, but by the joint and agreeing action of several, and sometimes many muscles. And as these muscles may vary to a great extent in their degree of contraction, the motions produced by them are not only compound, but are exceedingly varied. To illustrate this compound and varied character of motion, I will refer to a single example in which only two muscles are concerned in the motion. In Fig. 113 you see a pair of muscles, one of which is marked *h*, which extend from the large protuberances behind the ears to the top of the breast-bone. In the neck of a thin muscular person these muscles are very prominent. When they contract *equally*, the head is bent straight forward in the middle line between the muscles, and a line drawn from the middle of the forehead down to the breast-bone would strike exactly at the point where these two muscles unite. But if one muscle contracts more strongly than the

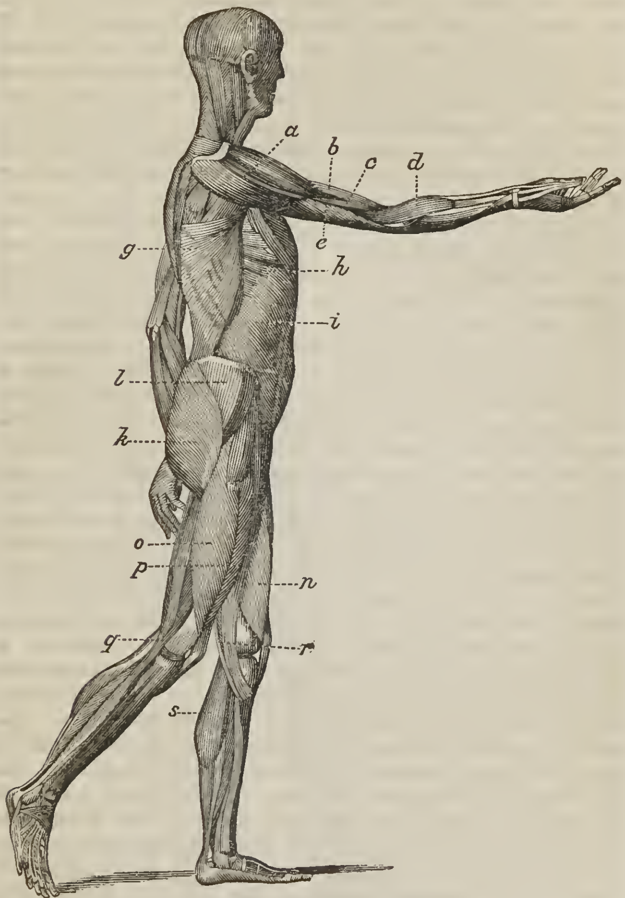
other, the head as it bows forward bows towards the side on which is the strongest contraction. And as the degrees of contraction in these two muscles may be endlessly varied, so there may be an endless variation in the degree of inclination of the head to one side or the other, as it is bent forward. If then so great a variety in the direction of motion may be produced by variation in the degrees of action in two muscles, you can readily see that an almost infinite variety of motion must result from this variation, where many muscles are called into action.

310. I know not any part of the body, which exemplifies in so palpable a manner the compound and diversified character of muscular motion as the tongue. It is mostly a bundle of muscular fibres, apparently mingled together in confusion, but really arranged in perfect order, so that it can be moved with great definiteness in all directions, forward, backward, upward, downward, to either side, and in all intermediate directions. If you stand before a glass, and opening your mouth, move the tongue rapidly about in all these directions, you think of a harlequin performing his antics. But all this wonderful variety of movement is produced in obedience to the definite action of nerves, whose fibres are mingled with the muscular fibres of the tongue. And in order to produce each motion there is an agreement of action not between merely many of these fibres, but between multitudes of them.

311. With the view which I have given you of the compound and varied character of muscular motion, you are prepared to take a general survey of the muscular system. For this purpose I call your attention to a side view of the muscles of the body as presented in Fig. 122. I must premise, that you can get no idea from this Figure of the number of the muscles in the body, for you see here only the outer layer of muscles, and there are many muscles concealed by them. You observe that they are of various shapes and sizes, according to the motions which they are designed to produce, and the circumstances in which they are placed. They are round, long, short, flat, fan-shaped, circular, serrated, &c. I will point out some of them. At *a* is the very large muscle that makes the fleshy prominence at the upper part of the arm, and the office of which is to raise the arm, carrying it out from the body. You observe that its fibres are not all arranged alike but lie in different directions. The result is, that while the arm is raised by the muscle as a whole, it may be carried at the same time forward or backward by the varying action of

External layer of the muscles of the body.

FIG. 122.



MUSCLES OF THE BODY.

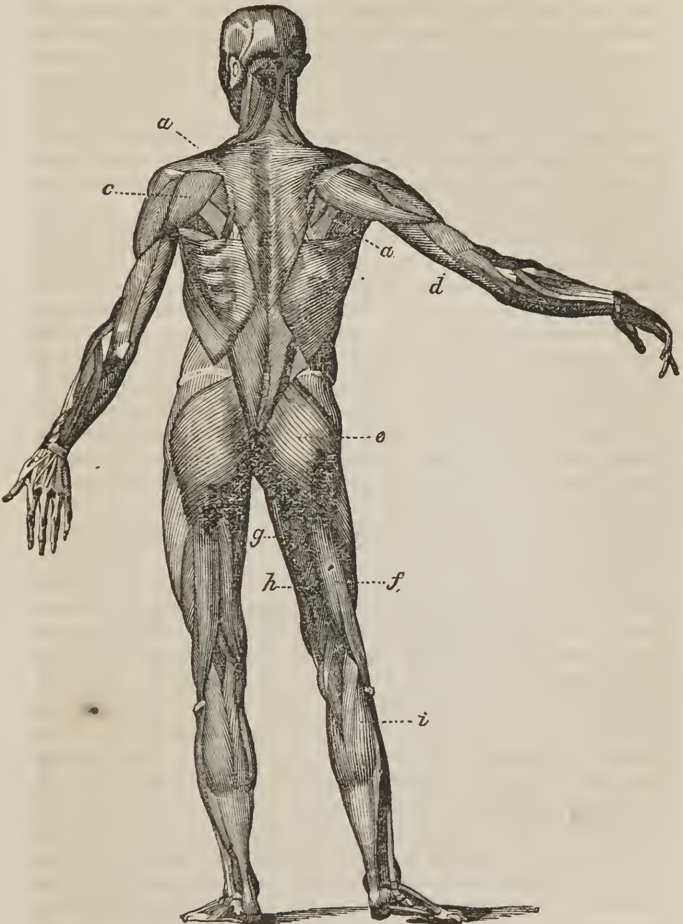
these different fibres. There are many of the muscles of the body which are made thus to produce various results by variation of the action of different parts of the same muscle. And the regulation of this variation by the nerves is one of the most wonderful and mysterious things which we find in our study of the nervous system. For each fibre in the cases referred to is told, as we may express it, just how much it must do in order to produce the requisite general motion of the muscle. It is manifestly much more wonderful thus to produce various but accurately graduated contraction in different parts of the muscle, than to produce an uniform contraction in all its fibres.

312. I go on with my notice of the particular muscles. At *b* is the biceps muscle, which bends the forearm upon the arm, and at *c* is another muscle that assists the biceps. At *e* is the large muscle in the back of the arm, which acts in opposition to the biceps, and straightens the forearm upon the arm. At *d* is a muscle which rolls the radius outwards, and thus turns the palm of the hand upward as seen in the Figure. At *g* is a very large broad muscle coming from the whole length of the back, and at the axilla or arm-pit, its fibres are collected, twisted, and folded upon each other. The muscle is fastened by a stout tendon to the upper and back part of the bone of the arm, and its office is to pull the arm backwards and downwards. At *h* is a serrated muscle, which rising from the ribs, goes to the shoulder-blade, and serves to draw the shoulder-blade forwards. At *i* is one of the broad muscles of the abdomen. At *l* and *k* are two large muscles that move the thigh. At *o* and *p*, as seen on the right thigh, and at *n*, as seen on the left, are three large muscles, which are fastened to the kneepan, and serve to throw the leg forward as described in § 304. At *q* is the tendon that forms the outer hamstring, and at *r* are the two tendons which form the inner one. The muscles to which these tendons belong, serve to bend the leg upon the thigh, drawing it upward and backward. At *s* is the muscle which makes the bulk of the calf of the leg. It lifts the heel upward and backward, and it is seen in action in the right leg of the Figure. Its strong tendon which is attached to the top of the heel bone is called, on account of its strength, the tendon of Achilles. This muscle is in Fig. 109, the power P which raises the weight of the body, W, on the fulcrum, F, as the heel is raised from the ground in walking.

313. In Fig. 123 you have a rear view of the muscles. At

Rear view of the external layer of the muscles.

FIG. 123.



REAR VIEW OF THE MUSCLES.

a is a very broad muscle, which rising from the back is attached to different parts of the shoulder-blade. You can see that this irregularly shaped muscle, will move the shoulder-blade variously, according to the various action of the different fibres of the muscle, which run in so different directions. At *c* you see the rear part of the muscle that raises the arm. At *b* is the extensive muscle that you saw in Fig. 122 at *g*, which draws the arm backward. At *e* is a large muscle that draws the thigh backward. At *g*, *h*, and *f* are the muscles whose tendons form the two hamstrings. At *i* is the muscle that forms the calf of the leg, and raises the heel.

314. I have thus described to you a few of the principal muscles in the body, that you may have some idea of the modes in which they act, and the manner in which they are arranged. Those which I have described are all muscles of considerable size. But there are some exceedingly small muscles in the body, producing some very delicate motions. For example, all the variations in the note of the voice result, as you will see in the Chapter on the Voice, from the variation of tension of the vocal ligaments, which is regulated by certain very small muscles. As the laborer sings over his work, great is the contrast between the delicate action of these little muscles, and the strong action of the muscles of his stalwart arm. A variation of less than a hair's breadth in the contraction of the muscles of the vocal ligaments suffices to produce an appreciable difference in the note of the voice.

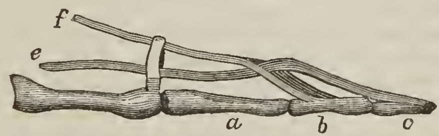
I have thus far spoken of the bones especially as being moved by the muscles. But other parts are moved by them also. In the case of the voice, just alluded to, the little muscles move cartilages to which the vocal ligaments are attached. The tongue and the palate are moved by muscles. Muscles move the skin. In man this is generally very much confined to the face. The mouth, the eyelids, the eyebrows, &c., are moved by muscles. In many animals the skin is moved extensively by muscles, as for example when the horse shakes his skin to get rid of the biting flies.

315. In the arrangement of the muscles great regard has been paid by the maker of our bodies to convenience and symmetry, and not merely to mechanical advantages. Thus, the muscles moving the fingers are mostly placed in the forearm, while the slender tendons pass over the surface of the bones in the wrist. The flowing outline of the arm is thus secured, and the hand is made a light, and at the same time, a strong ap-

paratus. The same can be said substantially of the arrangement of the muscles and tendons in the leg and foot. There is one arrangement in the foot which is worthy of especial notice. There is a muscle in the fleshy part of the leg, which by a long tendon, divided in the foot into four tendons, bends the last joints of the toes. There is also a short thick muscle in the bottom of the foot which joins the tendons of the first named muscle, and assists it in bending the toes. It is as if two different sets of men were placed in two different positions, with ropes arranged so as to pull in the same direction. The question arises, why the toes are not bent by a single muscle, lodged conveniently in the fleshy part of the leg. The reason probably is, that the muscle placed in the sole of the foot is needed there as a filling up in the arch of the foot, and so the force necessary to bend the toes is divided between the two positions.

316. There is another contrivance in this muscle that bends the toes which I will notice here. Its four tendons pass to the last bones in the toes, and in doing so they go through the tendons of the muscle that bends the second joints. These latter divide at their ends where they join the bones for this purpose. A similar arrangement also is made in the fingers for the tendons of the second and third joints. This is represented in Fig. 124,

FIG. 124.



in which *e* is the tendon which goes to the last bone *c* through the division in *f*, which goes to the second bone *b*. It is manifest that this is the best way of packing the tendons, as we may express it. Any other conceivable arrangement would add to the bulk of the finger. As they are represented in the figure they are raised up, instead of being closely packed down upon the bone, as they are in reality.

317. I have already alluded to the fact that many muscles unite in producing most of the movements of the body, and that, as they vary in the degrees of their contraction, the variety of motion resulting from both these causes, is exceed-

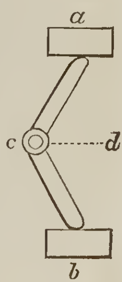
ingly great. I will now call your attention more particularly to these points, as you can more readily appreciate them after the general view which you have taken of the muscular system. Even when only a part of the body is put in motion, there are often many muscles engaged in the act. Take, for example, the act of swallowing, which I have described in § 78 in the Chapter on Digestion. In this compound act the muscles of the jaw close the mouth, the tongue thrusts the food back into the throat, the digastric muscle (§ 306), pulls up the larynx, and the epiglottis is at the same time shut down by muscles upon the opening into the larynx, to let the food slide over it. In speaking and singing the action of the muscles is much more complicated than in the act of swallowing. The muscles of the chest work the bellows of the organ (for such is the relation of the chest to the musical instrument, the larynx,) the muscles of the vocal ligaments put them in the state of tension required to produce the note intended, the muscles of the epiglottis raise it to let the sound out, and the muscles of the throat, palate, tongue, and lips, give articulation to the sound as it comes from the larynx. And observe, that some of the same parts are engaged in the act of speaking that are engaged in that of swallowing, but are put in different positions for the two acts. Thus, the epiglottis is raised up when we speak, and is shut down when we swallow, and the larynx is raised up when we swallow, and is drawn down again when we speak. And how quickly we pass from the one act to the other, as we mingle our talking and eating together! And we do it with such facility and precision, that it is a very rare accident that a crumb or a drop slips into the larynx. Observe farther, that when we take a breath, as well as when we speak, the epiglottis must be raised, the air passing in, instead of passing out as in speaking. The parts, therefore, are often engaged in these different acts, not only distinct from each other, but inconsistent with each other also, and they change from one of these acts to another so readily, that as we eat, and breathe, and talk, we are conscious of no disturbance, and scarcely ever of any effort in the change. No change of action in any machinery of man's invention can be at all compared with this in the precision and facility of the change, much less in its complicated character.

318. But if there be complication and variety of action when but one part of the body is put in motion by the muscles, there will be vastly more when the muscles of the body as a whole are brought into action. If you look at Fig. 122, you see the

muscles generally in more or less action, and the action of each one has its particular relation to the attitude assumed. If now the attitude be varied, this particular relation of each muscle must be varied also. If, for example, the right foot be carried forward so as to bring the weight of the body on to that foot, instead of the left, on which it now rests, as represented in the Figure, all the muscles of the frame will have a different relation in their action. And not only this, but while the body is changing from the one attitude to the other, there will be a continual change of this relation. At no one moment during the act or motion, which changes the attitude, will the state of contraction in each muscle be precisely the same, that it is at any other moment. Thus, the state of the muscles in the beginning of the change of attitude is altogether different from what it is when the movement is half accomplished. And the same can be said of any other two points in the progress of the movement. The same is true of any other general action of the muscles. Thus, if one is pulling with his feet braced, the muscles do not remain in the same relative condition all the time, but as the body which is pulled yields, the relative tension of the muscles is changed every moment. But there is no movement which exemplifies this change of relative condition of the muscles so well as that of balancing. If with the views which I have presented in your mind, you observe some one who is skillful in balancing, you will be impressed with the ever changing but precisely regulated degree of tension in the different muscles, and with the variety of combination in their action.

319. I will not comment to any extent upon the general movements and attitudes of the body. But I will here simply call your attention to one mode of action, in which a large number of the muscles are called into play, on account of its analogy to an expedient often used in mechanics. I refer to what is called the *toggle-joint*. This I will explain. Let *c*, *a*, and *c*, *b*, represent two bars connected together, like a carpenter's folding rule, by a hinge or joint at *c*. Suppose the two ends, *a* and *b*, to be fitted into the two blocks represented in the Figure. If now the block at *b* is fixed, and the block at *a* is movable, and force be applied to the joint *c* carrying it towards *d*, the block at *a* will be

FIG. 125.



TOGGLE-JOINT.

pressed upward with considerable power. If on the other hand, the block at *b* is movable, and that at *a* is fixed, the block at *b* will be pressed downward. We see this latter form of the contrivance applied in printing presses. In the human body this toggle-joint is used in both ways. When one stoops to take a heavy weight upon his back or shoulder, he puts both the knee and the hip-joints into the condition that the toggle-joint is when it is bent; and then as he straightens up, the weight is raised by an action of the joints precisely similar to that of the toggle-joint in machinery. In the case of the knee, the straightening of the joint is done by the muscles on the front part of the thigh, that draw up the kneepan with the tendon attached to it. This is using the principle of the toggle-joint in pressing *upward*. It is also sometimes used in pressing *downward*. In crushing any thing with the heel, we give great force to the blow on the principle of the toggle-joint, by flexing the knee and straightening the limb as we bring down the heel upon the thing to be crushed. In pushing any thing before us, we bend the elbow as preparatory to the act, and then thrust the arm out straight, thus exemplifying the toggle-joint. The horse gives great force to his kick in the same way. The great power exerted by beasts of draught and burden is to be referred very much to the principle of the toggle-joint. When a horse is to draw a heavy load, he bends all his limbs, especially the hinder ones, and then as he straightens them, he starts the load. In this case the ground is the fixed block of the mechanism, the body of the horse to which the load is attached is the movable one, and his limbs are so many toggle-joints. By this application of the principle we see draught horses move very heavy loads. " So, (admitting fable to be fact,") says Dr. Griscom, " when the farmer, in answer to his petition for assistance, was commanded by Hercules to exert himself to raise his wagon from the pit, he placed his shoulder against the wheel, and drawing his body up into a crouching attitude, whereby all his joints were flexed, and making his feet the fixed points, by a powerful muscular effort, he straightened the toggle-joints of his limbs, and the wheel was raised from its bed of miry clay. His horses at the same moment extending their joints, the heavily laden wagon was carried beyond the reach of farther detention."

320. The hand is the most wonderful of all parts of the body, in regard to variety and complication of movement. There are over fifty muscles, which are engaged in the various

motions of the upper extremity, all of which, of course, have more or less reference to the hand. Indeed the hand is the part of the upper extremity to which all its other parts are tributary, and therefore we may properly consider all these muscles as in a great measure belonging to the hand. If now you call to mind the fact, that each one of these muscles can vary the *amount* of its contraction in all degrees, from the most powerful action down to the slightest movement, you can readily see that fifty muscles with this power of variation can produce an almost endless number of combinations of motion. The variety would be exceedingly great, even if every muscle, whenever it acted, had always the same amount of contraction. But the power of varying the amount of contraction multiplies the variety to an inconceivable extent.

321. If you watch the movements of the hand with its fingers, as you exercise it in a great variety of motions, you can get some idea of its capabilities in this respect. If, too, you observe its movements in different individuals in all kinds of labor and handiwork, you will be still more impressed with the extreme variety of its movements. It is capable of performing the heaviest and rudest work, and at the same time the most delicate. How wide the difference between wielding the ax or the sledge-hammer, and moving the engraver's tool in some of the finest productions of his art! How firm is its grasp of the hammer, and yet how gentle is its pressure upon the graver, as it moves it in almost invisible lines! The shape of the hand, with its fingers of unequal length, and its thumb opposite to them, capable of touching the tip of each of the fingers, or all of them together, enables it to accommodate itself to a vast variety of shapes and sizes of objects; and its delicate papillæ, filled with nerves, and arranged in rows, as you can see, on the tips of the fingers under the skin, endow this wonderful instrument with a sensibility which guides its muscular movements. When, therefore, we consider the almost endless variety of its motions, the delicacy and accuracy of its sense of touch, and besides these, the force and grace with which it acts in the expression of thought and feeling, we hardly wonder that some have fixed upon the hand as man's distinguishing characteristic, and we are impressed with the thought, that it is a fitting instrument of work and expression for that mind, which is the image of God in man.

322. Having thus taken a survey of the muscular system, let us look for a moment at the whole machinery, as it works when

it is engaged at the same time in some general movement, and in some special movements of some departments of it. Look, for example, at some one who is busied in conversation while he is walking, and is perhaps at the same time twirling something in different directions in his fingers. Here you have a general action of the muscles as described in § 318, and with it a particular action of two sets of muscles in two different parts of the body; and yet so well do the nerves regulate these various movements, that there is no disturbance or confusion in the complicated machinery. While the muscles of the arm and fingers are at work executing their diversified motions, the little muscles of the larynx are ever varying the notes of the voice, and the muscles of articulation are putting that voice into every variety of shape. And while these movements are going on in these particular parts of the system, the machinery as a whole is executing one of its grand general movements. And besides all this, the muscles of respiration are at work all the while, introducing air into the lungs to change the blood, and forcing it out through the trachea to make the vocal ligaments vibrate; and that compound muscle the heart is pumping at the rate of seventy times a minute sending the blood through its tubes every where; and if there be any food in the stomach, the muscular fibres of that organ are at work churning the food to make more blood. How complicated is the machinery that performs all these operations, and yet with what precision every muscle, nay, every individual fibre works in obedience to the nerves!

323. The question arises, how in all the diversified action of the muscles their nice adjustment is effected. How do the muscles *know*, as we may express it, just how much to do in each movement? When, for example, you reach your hand up to touch some object, how does each muscle know just what degree of contraction is necessary to make the hand go with precision to the particular point arrived at? And so when one is playing on an instrument with the fingers, as the piano, varying their pressure continually in accordance with the desired loudness of the sound, how does each muscle know just what amount of contraction is required of it in each movement? Though the senses of vision and touch afford some assistance in the guidance of muscular action in such cases, something else is manifestly necessary. Sir Charles Bell, therefore, supposes that there is what he calls a *muscular sense*, which acts as a guide to the muscles, in connection with the senses of sight and touch. In some cases it is the sole guide. On this subject, Sir Charles

says, " When a blind man, or a man with his eyes shut, stands upright, neither leaning upon or touching aught; by what means is it that he maintains the erect position? The symmetry of his body is not the cause; the statue of the finest proportion must be soldered to its pedestal, or the wind will cast it down. How is it, then, that a man sustains the perpendicular posture, or inclines in due degree towards the winds that blow upon him? It is obvious that he has a sense by which he knows the inclination of his body, and that he has a ready aptitude to adjust it, and to correct any deviation from the perpendicular. What sense then is this? for he touches nothing, and sees nothing; there is no organ of sense hitherto observed which can serve him, or in any degree aid him. Is it not that sense which is exhibited so early in the infant, in the fear of falling? Is it not the full development of that property which was early shown in the struggle of the infant while it yet lay in the nurse's arms? It can only be by the adjustment of muscles that the limbs are stiffened, the body firmly balanced, and kept erect. There is no other source of knowledge, but a sense of the degree of exertion in his muscular frame, by which a man can know the position of his body and limbs, while he has no point of vision to direct his efforts, or the contact of any external body. In truth, we stand by so fine an exercise of this power, and the muscles are, from habit, directed with so much precision, and with an effort so slight, that we do not know how we stand. But if we attempt to walk on a narrow ledge, or stand in a situation where we are in danger of falling, or rest on one foot, we become then subject to apprehension; the actions of the muscles are, as it were, magnified and demonstrative of the degree in which they are excited."

324. It is obvious then that this muscular sense informs the mind of the changing postures of the body, and guides the muscles in effecting these postures. And it has a particular set of nervous fibres devoted to it, separate from those fibres which excite the muscles to action, though they are ordinarily inclosed in the same sheath. This sense, it may also be remarked, is a source of pleasure, as well as the other senses. The motions of the body are attended with a sense of enjoyment, which lightens labor, and adds zest to our active sports. The enjoyment of the muscular sense we see constantly exemplified in the gambols of animals. It may be still further remarked, that this sense is capable of being educated like the other senses. But of this I shall speak in another place.

CHAPTER XIII.

LANGUAGE OF THE MUSCLES.

325. As the nerves of sensation are the inlets of all knowledge to the mind, the nerves of motion are the outlets by which all knowledge is communicated. Thought and feeling are expressed only by muscular motion. It is true that there are some accompanying and subordinate modes of expression, as the flowing of tears, the action of the capillaries producing blushing, and the paleness occasioned by fear. But these could not of themselves alone communicate thought and feeling, and can do so only by being associated with other signs. They only add force to the expression already produced by muscular action. Indeed they are signs which can not be understood, unless muscular action interpret them. Thus if tears flow, we know not whether they are tears of joy or sorrow, except as the expression of the countenance informs us; and expression, as I shall show you in this chapter, is wholly the result of the action of muscles. So too, the muscles of the face tell us, whether the blush that mantles there is the blush of shame, or of modesty. And when we see paleness caused by fear, we know that this is the cause, only from the expression of the countenance and the attitude of the body, which may very properly be called the expression of the body, though it is much less marked than the expression of the countenance.

326. It is by the voice chiefly that thought and feeling are communicated. And every variation of note, or of articulation, is caused, as I shall show you in the next chapter, by the action of muscles. When the muscles of the hand communicate to others thought and feeling by writing, they merely translate the language of the muscles of the vocal organs into conventional signs. Leaving the language of these vocal muscles for another chapter, I shall in this notice the language of the other muscles of the body and especially of those of the face.

327. As we watch an animated speaker, we see that it is not the face alone, that adds force to his utterances by its corresponding expressions. Various parts of the body in a measure do the same thing. The head is nodded or shaken, the shoulder is shrugged, the foot is stamped, and above all, the hand exe-

cutes a great variety of motions, in correspondence with the thoughts and feelings which the mouth utters. Sometimes too, the whole frame is brought into action. The gestures and the attitudes, which are but gestures of the whole body, are important aids to the orator in conveying his thoughts and feelings into the minds of his auditors.

328. This language of the muscles is used to a greater extent than we are conscious of in our ordinary intercourse. We are not aware how much we communicate in this way. This language is by no means confined to those palpable acts which this subject suggests at once to the mind,—the broad laugh of merriment; the sighing, and sobbing, and weeping of grief; the stamping of the foot in anger; the pointing of the finger in calling attention to any particular subject; the gesture used in beckoning one to come to you, &c. But it includes numerous little and scarcely observed motions, which in great variety add to the significance of the words which we utter. And in the case of the countenance, far more is communicated in the aggregate by the constant gentle play of the muscles, than by the broader and more palpable expressions, which are occasionally produced by their stronger action. The deaf mute can gather from the language of the muscles, as it accompanies the voice that he can not hear, much more information as to the passing conversation than one would suppose that he could. And the full capabilities of this language we can only learn, by observing to what wonderful extent the deaf and dumb can communicate with each other by the use of natural signs, without any aid from those which are artificial.*

329. While in man the muscles of the face are the chief agents of expression, in other animals the very limited expression of which they are capable, is chiefly effected by other parts of the body. For example, the dog wags his tail, the cat puts up her back, the game-cock spreads out his ruff of feathers on his head, &c. Rage is almost the only passion which can be expressed by animals in the countenance. They can snarl, but

* I was much struck with an illustration of the great range of the language of natural signs, in an exhibition made many years ago by the lamented Gallaudet before the legislature of Massachusetts. Previous to exhibiting the attainments of his pupils, he requested, that if any deaf and dumb person who had not been educated in an asylum were present, his friends would bring him forward, that he might show how much could be communicated by natural signs. A man came forward, and Mr. Gallaudet learned from him by natural signs alone such facts as these,—the place of his residence, the fact that his parents were living, the number of his brothers and of his sisters, the fact that he had seen Mr. G. before in a certain place, &c. Any one, it may be remarked in this connection, who has been engaged in teaching the deaf and dumb, and who has, therefore, become skilled in the use of sign-language, can converse quite readily by signs with foreigners from any part of the world.

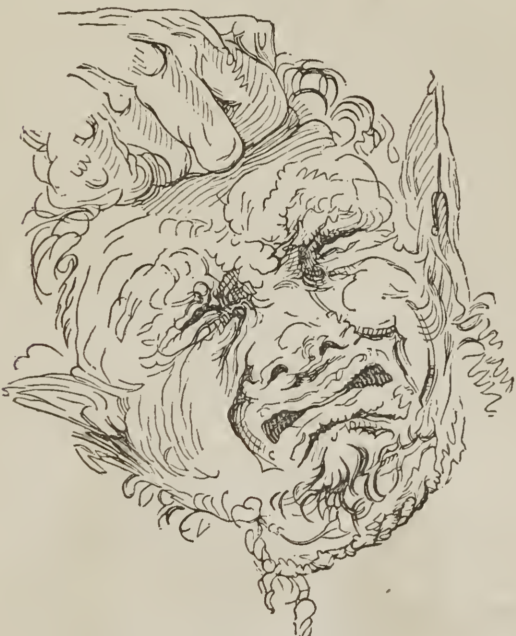
they can not laugh or cry. Hence it has been said, that man can be very properly distinguished from other animals by calling him "a laughing and crying animal."

330. Though the variety of expression in the human countenance is very great, it is ordinarily produced by the action of very few muscles. The principal muscles are these—the muscle that wrinkles the eyebrow, causing frowning; the muscles which draw down the corners of the mouth; and those which draw them up. When a smile occurs, it is produced by the muscles which raise the corners of the mouth. When sadness is expressed, it is done by the muscles by which the corners of the mouth are drawn down. Hence the origin of the common expression, "down in the mouth." In laughter, the muscles which raise the corners of the mouth act strongly, wrinkling the cheek, simply because the corner of the mouth is carried up so far as to push up the cheek before it. One other muscle is brought into some action—the circular muscle which closes the eyelids—for the eyelids are brought nearer together in laughter, though in mere smiling they are not. In Fig. 126, representing broad laughter, you see the two effects spoken of above, the wrinkling of the upper part of the cheek,

FIG. 126.

and the partial closure of the eyelids. In weeping, the muscles that draw down the corners of the mouth, which in the mere expression of sadness act slightly, now act strongly. At the same time the frowning muscle wrinkles the eyebrow. In ordinary weeping it does so but slightly, but in weeping from pain this muscle is strongly contracted. So it is also when there is crossness mingled with the grief. Fig. 127,

FIG. 127.



which is the face of a faun weeping from pain, illustrates these points. Sir Charles Bell, from whose work on the Anatomy of Expression most of the figures in this chapter are taken, says that he represents the expression of weeping in the face of a faun, because it is mean and ludicrous as seen in the countenance of man.

331. It is very commonly supposed that the eye has much

to do with the expression of the countenance, and hence such phrases as these are in universal use—a speaking eye; a wild eye; the witchery of the eye; the eye flashed, &c. But the eye of itself has no active agency in expression. The muscles which move it have, but not to any great extent ordinarily. Of them I shall speak in another part of this chapter. The apparent expression which the eye has is merely apparent, and not real. It results altogether from the position of the parts about the eye. This can be proved to you by any portrait painter. It is related of an artist that, when a royal visitor was admiring a sketch of the face of a weeping child, he said to him, "has your majesty a mind to see how easy it is to make this very child laugh?" As the king said that he should like to see it, the artist rubbed out a little at the corners of the mouth and on the eyebrows, and added a few strokes to represent the corners of the mouth as raised, and the eyebrows as without wrinkles, and the face, which was the moment before the very picture of grief, now exhibited a merry laugh. Afterward he as readily restored the original expression. Now in this case there were the same eyes in the two expressions. The alterations were made only in the neighboring parts, and the same eyes were apparently weeping eyes at one time and laughing ones at another.

332. In Fig. 128 and 129 you can see how much the mouth alone affects the expression of the whole countenance. The apparent expression of the eye is wholly altered by the

FIG. 128.

FIG. 129.

to do with the expression of the countenance, and hence such phrases as these are in universal use—a speaking eye; a wild eye; the witchery of the eye; the eye flashed, &c. But the eye of itself has no active agency in expression. The muscles which move it have, but not to any great extent ordinarily. Of them I shall speak in another part of this chapter. The apparent expression which the eye has is merely apparent, and not real. It results altogether from the position of the parts about the eye. This can be proved to you by any portrait painter. It is related of an artist that, when a royal visitor was admiring a sketch of the face of a weeping child, he said to him, "has your majesty a mind to see how easy it is to make this very child laugh?" As the king said that he should like to see it, the artist rubbed out a little at the corners of the mouth and on the eyebrows, and added a few strokes to represent the corners of the mouth as raised, and the eyebrows as without wrinkles, and the face, which was the moment before the very picture of grief, now exhibited a merry laugh. Afterward he as readily restored the original expression. Now in this case there were the same eyes in the two expressions. The alterations were made only in the neighboring parts, and the same eyes were apparently weeping eyes at one time and laughing ones at another.

332. In Fig. 128 and 129 you can see how much the mouth alone affects the expression of the whole countenance. The apparent expression of the eye is wholly altered by the

FIG. 128.

FIG. 129.

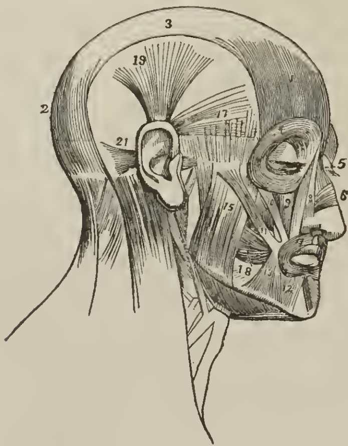
change about the mouth. If we could add at the same time a change at the eyebrows, the expression of the eye would be much more affected.

333. The language which is ordinarily used, in relation to the agency of the eye in the expression of the countenance, implies that the eye itself, apart from any motion, changes in the changing expression. How this is done is not inquired; but there seems to be an ill defined notion that the animal spirits, as it is expressed, flow into the eye more or less freely with the changing feelings, or that a nervous influence is exerted in some way upon the eye, altering its appearance. These notions are so universal, and are so inwrought into our language, and especially the language of poetry, that scientific men even are apt to use the expressions to which they give rise, in their descriptions of the language of the passions. Even Sir C. Bell, in his celebrated book on the Anatomy of Expression, in describing the expression of the emotion of joy, uses the phrase, the eye is lively and sparkling. Let me not be understood to mean, that I would have the expressions, in such universal use in common language and in poetry, given up. I would as soon claim that the expression, the sun rises, should be abandoned in common language. But as the astronomer would have it understood, that the apparent fact, that the sun rises, is only apparent, not real, so as a physiologist, I would have it understood, that the apparent active agency of the eye in the expression of the countenance is not real. And as it would be objectionable to speak of the sun as rising, in a book on astronomy, so in a professional book on the Anatomy of Expression it is objectionable, in a description of the physical signs of an emotion, to use the common phrases in regard to the agency of the eye in expression.

334. Having thus noticed the principal muscular motions that are concerned in the expression of the countenance, I propose now to go more extensively into the subject, and show you how other muscles, besides those to which I have alluded, act in producing certain expressions. I shall also show how the expressions are varied by combinations of muscular action, for it is as true of the muscles of expression in the face, as it is of the muscles generally, as stated in § 309, that almost every movement is produced, not by the action of one muscle alone, but by the action of several, sometimes many muscles. The various expressions of the countenance are all of them compound results, some of them more so than others.

335. I will first call your attention to the particular muscles of expression in the face, and indicate their mode of action. They are represented in Fig. 130. There is a thin flat muscle

FIG. 130.



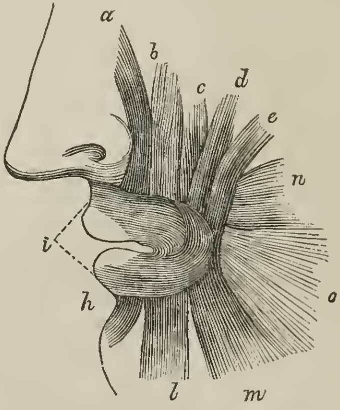
MUSCLES OF THE FACE.

covering the whole top of the head, represented at 1, 2, and 3; 3 being its thin tendinous part. It is fastened to the large bones behind, and in front its fibres end in the skin of the forehead and the eyebrows, and in the circular muscle of the eyelids, 4. When it contracts, therefore, it raises the skin of the forehead and the eyebrows; and if it contract strongly, it wrinkles the forehead. The circular muscle of the eyelids, 4, when it contracts closes the eye. This and the large frontal muscle just described, you can see, must have much to do with the expression of the countenance. There is a very important though small muscle which is not seen on this figure. You see it on Fig. 113, at *a*. It is attached to the bone at the side of the top of the nose, and is inserted into the skin of the eyebrow. It is called the *corrugator supercilii*, or wrinkler of the eyebrow. From the agency which this muscle has in the expression of certain passions and emotions, comes the word in so common use, *supercilious*. Though a little muscle, it is

truly a supercilious one. It has, as you will see as we go on, a large play in many varieties of expression, produced by combinations of action in the muscles of the face. There are two muscles on the nose, 5 and 6, which compress the nose, and wrinkle its skin. They have some agency in certain expressions of the countenance. At 7 is the circular muscle of the mouth. When this contracts it closes the lips, and if it act strongly it pushes them out. This is the muscle with which in part pouting is done. At 8 is a muscle which is fastened above to the bone of the nose, and runs down, its fibres ending in the wing of the nose, and in the upper lip. When it contracts, therefore, it moves the wing of the nose outward, and draws up the lip. You see this muscle in action in some emotions, the nostrils appearing spread out. At 9 is a muscle which raises the lip, and at 10 and 11 are two muscles, that raise the corner of the mouth, carrying it a little to one side. At 13 is the muscle which acts in opposition to the two last. It pulls the corner of the mouth down. At 12 is the muscle which pulls down the lower lip. At 18 is the muscle in the side of the mouth, which draws the corner of the mouth backward, and also serves to press the cheek inward, and thus prevent the food from getting outside of the teeth when we are chewing it. This muscle also, by its compressing power, forces out the air from the mouth when the cheeks are distended, as in blowing a horn or a trumpet. Hence it is called *buccinator*, from *buccinare*, to blow a trumpet. At 15 is a large muscle which closes the lower jaw against the upper, and although its chief use is to masticate the food, it has some agency in the expression of the countenance, in fixing the teeth firmly together, as in the expression of rage. There are three muscles which move the ear; 19, moving it upward; 17, forward; and 21, backward. These have but little power in man, but in some animals they move the ear considerably, and are prominent agents of expression.

336. In Fig. 131 the muscles about the mouth, which have so much to do with the expression of the countenance, are very distinctly shown. At *a* is the muscle which draws up the wing of the nose and the lip; *b* raises the lip; *c* raises the corner of the mouth; *d* and *e* raise the corner of the mouth, and at the same time carry it outward; *n* draws it outward; *m* draws it downward and outward in which it is assisted by a broad thin muscle, *o*, which situated just under the skin comes up from the neck; *l* draws the lower lip downward; and *i* is the cir-

FIG. 131.



MUSCLES ABOUT THE MOUTH.

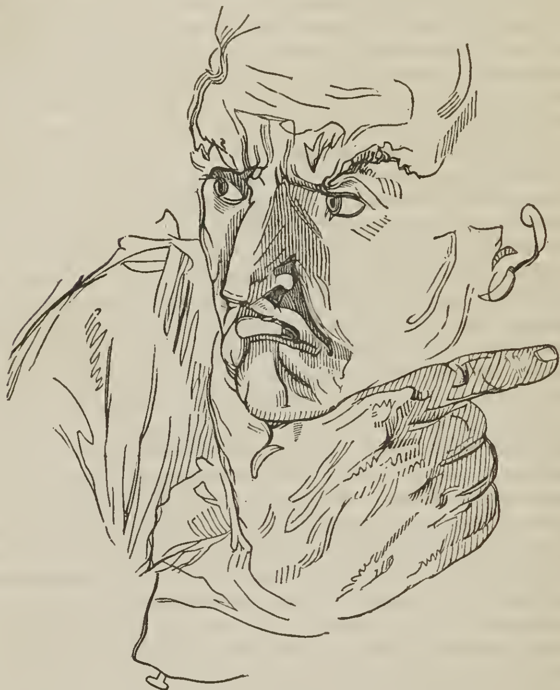
cular muscle which closes the lips, and thrusts them out in pouting. At *h* is a short muscle which is fastened to the sockets of the teeth, and has its fibres ending in the skin of the chin. It therefore draws the chin up when it contracts. It has so much agency in the expression of scorn and contempt that it has been called the *superbus*. It is by the action of this muscle, together with the circular muscle *i*, that the expression termed pouting is produced. The muscles which I have thus described are all in *pairs;* and in every pair both muscles contract always exactly alike, unless affected by disease. We laugh and frown and weep on both sides alike. All of these muscles of expression in the face are governed in their action by the branches of one nerve, the respiratory nerve of the face. When this nerve, therefore, is paralyzed on one side, and not on the other, as is no uncommon occurrence, these muscles on the paralyzed side are motionless, and the individual can laugh and frown and weep on only one side of the face. In Fig. 82 you have illustrated the result of this partial paralysis, the face being perfectly quiescent on the left side. The contrast would have been still greater if the face had been represented as in more decided action, as laughing, for example.

337. Having thus described the muscles of the face which are the agents of expression, I will now show their action in the expression of different passions and emotions. And I remark, that you will see, as I proceed, that so far from there being any one muscle devoted to the expression of one emotion or passion, expression is commonly the result of the combined action of many muscles. And you will also see that, by virtue of this combination, the same muscle often takes a part in the expression of various emotions.

338. When the frontal muscle (1, 2, 3, Fig. 130) contracts it raises the eyebrows. This motion expresses either doubt or surprise, and the observer determines which it is, by the expression of other parts of the countenance accompanying it, or in other words, by the action of other muscles in the face. When this muscle contracts very strongly, it draws up the eyebrows so much, as to push up the skin of the forehead, and wrinkle it. This, as you will soon see, is one of the many motions of the face which make up the expression of great bodily fear. In joy this muscle acts moderately, raising the eyebrow, therefore, but a little. This muscle often acts in connection with the *corrugator supercilii*, the wrinkler of the eyebrow. This may be seen in Fig. 132, respresenting a testy, peevish, jealous melancholy. Here the corrugator and the frontal muscles are both in strong action. You see also in this face certain muscles about the mouth acting forcibly. The muscle which draws the corner of the mouth down is in action while the *superbus* (*h*, Fig. 131,) is drawing up the chin which pushes up the lip before it. At the same time the muscle which draws up the wing of the nose and the lip, (*a*, Fig. 131,) contracts to some extent, producing an arching of the mouth, and a peculiar shape of the wings of the nose. The upper lip is arched by the action of this muscle in such a way, as to fit the arching upward of the lower lip, produced by the *superbus* and the muscle which draws down the corner of the mouth.

339. In the expression just described, and illustrated by the figure, you see that the muscle which draws down the corner of the mouth has a considerable agency. Now, this muscle is the chief agent in the expression of sorrow, as you saw in the first part of this chapter. The difference in the two cases lies in the *combination* of action of the muscles. Thus, in sorrow the muscle which draws down the corner of the mouth, does not have the *superbus* to act with it, as in the case of the passion, or rather compound feeling, represented in Fig. 132.

FIG. 132.



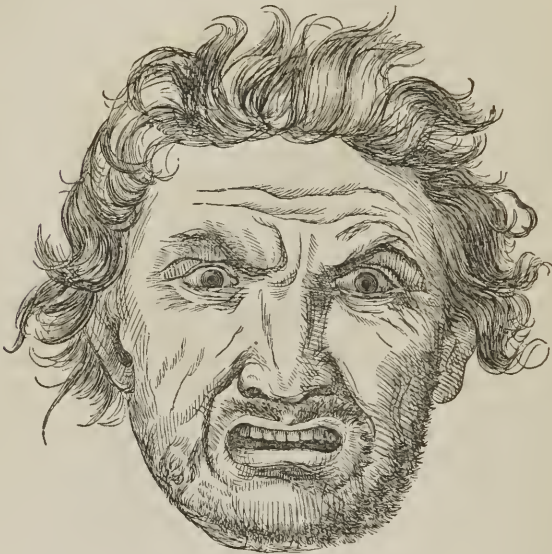
So also, in some forms of grief the *corrugator supercilii* acts quite strongly, as seen in Fig. 127, where the grief is represented as caused by bodily pain. It performs a different office in this case from what it does in the case of the expression represented by Fig. 132, simply through the accompanying action of other muscles, thus illustrating the effect of combination in muscular action in varying the character of the expression. I have already alluded to the different degrees of action in this muscle in different forms of grief in § 330. In quiet sorrow this muscle is not in action, but there is a general languor relaxing the muscles of the face, while the corners of the mouth

are slightly depressed. It is a state of the muscles directly opposite to that which exists when there is a calm quiet pleasure. Then most of the muscles are in a state of gentle action, and the corners of the mouth are a little raised, giving the radiance of a light smile to the whole countenance. The frontal muscle, slightly raising the eyebrows, adds to the effect.

340. The attitude, for so we may call it, of the countenance in admiration, is quite nearly allied to that which I have just described. The brow is expanded by the action of the frontal muscle, and there is a slight smile produced by the raising of the corners of the mouth. But the expression differs in some respects from that of mere pleasure. The frontal muscle acts rather more strongly in the former than in the latter, the eye is more wide open, and is fixed upon the object of the admiration, and the mouth is apt to be open, the jaw falling a little, so that we can see the edge of the lower teeth and the tip of the tongue. In both pleasure and admiration the expression varies much in different individuals, according to their temperaments, being characterized by activity in some, and in others more by relaxation or even languor.

341. Let me now call your attention to an expression of the countenance, in which many of the muscles are in a state of strong action. I refer to the expression of rage represented in Fig. 133. The combination of muscular action here is quite extensive. The *corrugator supercilii* acts forcibly, but unsteadily, as is the case with the action of all the muscles in the expression of this passion. The frontal muscle acts at the same time, raising the eyebrows. The eyes are opened widely, showing the rolling eyeballs. The muscle that raises the upper lip, *b*, Fig. 131, and the muscle that raises the wing of the nose and the lip, are in strong action. The nostrils are therefore spread out to the utmost, and the upper lip is drawn upward. But as the circular muscle of the mouth also acts strongly, there is only that part of the upper lip to which the muscles, *a* and *b*, Fig. 131, are attached, that can be drawn up. This point is just where the sharp eye-teeth, or *canine* teeth, as they are sometimes called, are situated. They are therefore seen laid bare. This allies man to the snarling brute, that shows his sharp teeth in his rage. Cooke, the tragedian, is said to have had great power in the use of these muscles. "In him," says Sir Charles Bell, "the *ringentes* (the snarling muscles) prevailed; and what determined hate could he express, when, combined with the oblique cast of his eyes,

FIG. 133.



he drew up the outer part of the upper lip, and disclosed a sharp angular tooth !" In rage the teeth are firmly closed by the muscles which move the lower jaw, and when utterance is given to it by the voice, these muscles but slightly relax to let the words out through the almost closed teeth, and are rigid again as soon as the words are finished.

342. The expression of mere bodily fear, represented in Fig. 134, is very different from that of rage, although some of the muscles act in the same way in both. The frontal muscle acts very forcibly, raising the eyebrows to their utmost extent, and the eyeballs are largely uncovered, giving to the eyes a broad stare. The *corrugator supercilii* is perfectly relaxed, while in rage it is strongly contracted. The lip is raised and the nostrils are spread out by the same muscles, *a* and *b*, Fig. 131, which act so forcibly in rage. But the circular muscle of the mouth, *i*, is relaxed, so that the whole lip is raised, instead of

FIG. 134.

a part of it, as is the case when rage is expressed. The lower jaw is fallen, while in rage it is in the opposite condition. The hair is raised up by a general action of the whole frontal muscle, 1, 2, 3, in Fig. 130.

343. The muscles of the eye, that is, those which move the eyeball have some agency in certain expressions of the countenance. Thus, in admiration, the fixing of the eye upon the admired object makes a part of the expression. In the expression of devotion the eye turns instinctively upward. There are certain involuntary motions of the eyeball, which have much to do with expression in certain states of the body, and in certain emotions. These motions are performed by the oblique muscles (§ 307.) When the straight muscles which ordinarily control the motions of the eye lose their power from a state of general insensibility, the eye is given over to the action of these oblique muscles, which are involuntary, and therefore is

rolled about in its socket, being turned upward all the time, so that the white of the eye only is seen. This occurs in sleep, in fainting, in the stupor of disease, and in the approach of death.

344. The loss of power in the voluntary muscles of the eyeball and eyelid is often seen ludicrously exhibited in the intoxicated man. He squints and sees double from deficiency of action in the straight muscles of the eyeball. The oblique involuntary muscles of course roll the eye in proportion to the deficiency of these straight muscles. The voluntary muscle too, which holds up the upper lid, fails to do its duty, and the lid is constantly disposed to fall over the eye. The frontal muscle is therefore called upon to aid it. Hence, in the effort of the drunkard to keep his eyes open, you see him raise up the eyebrows, the eyelids being of course dragged up after them to a little extent. "It is," says Sir Charles Bell, "the struggle of the drunkard to resist, with his half-conscious efforts, the rapid turning up of the eye, and to preserve it under the control of the voluntary muscles, that makes him see objects distorted, and strive, by arching his eyebrows, to keep the upper lid from descending. The puzzled appearance which this gives rise to, along with the relaxation of the lower part of the face, and the slight paralytic obliquity of the mouth, complete the degrading expression."

345. I have thus pointed out the agency of the several muscles that are engaged in the expression of the countenance. Most of them are peculiar to man, being found in no other animal. The inferior animals are variously endowed in regard to muscles of expression. But even those that have the most expression, have but few of those muscles which we find in the face of man devoted to this purpose. They have the muscles that move the eyes, those which raise the upper lip and thus expose the teeth, and to some extent those which distend the nostrils. The horse is especially endowed in regard to this latter motion. In that glowing and beautiful description of the horse in Job it is said, "the glory of his nostrils is terrible." But most animals, even of the higher orders, have but a limited motion of the nostrils compared with man. In him they have much more to do with the expression of the countenance than is commonly supposed. Their chief agency is in the expression of the nobler passions, and Sir Charles Bell remarks, that the great tragedians, Mrs. Siddons and Mr. John Kemble, exhibited their power in this respect in a remarkable manner.

346. None of the inferior animals have the *corrugator supercilii.* Indeed they have no eyebrows to move. The eyebrow

is a strong peculiarity of man, and in view of its agency in the expression of the countenance, varied as it is by the frontal muscle and the corrugator, it has been said by some one, that it is "the rainbow of peace, or the bended bow of discord." So also, the muscles that raise and depress the corners of the mouth are wholly peculiar to man. It is sometimes said that the dog smiles. But if you observe him closely, you will see that as he separates his lips or opens his mouth, at the same time that he wags his tail, there is no raising of the corners of the mouth, and therefore no true smiling. The idea that he smiles has come from mere association with other motions by which he indicates pleasure. The same can be said of the expression of sorrow in the dog and other animals. There is little of it in the face itself, amounting to nothing more than a mere downcast look, if even that; and we connect the idea of sorrow with the face, by the force of association, from hearing the cries and witnessing the movements which distress produces. The grand peculiarities of human expression are in the muscles whose action I have noticed in this paragraph, viz., the muscle that wrinkles the eyebrow, the muscle that raises it, and those muscles which move the corners of the mouth up and down. No animal but man can frown, or weep, or laugh, for it has not the muscles by which these acts are done.

347. Fear and rage are almost the only passions that are expressed in the faces of animals. And in some of them there are special provisions in muscular endowment, for the expression of these mere brutal passions, particularly for rage. Thus, in beasts of prey the *ringentes*, or snarling muscles have great power. They raise the lip strongly, and display the sharp long teeth which are to rend their prey in pieces. The eye too is made terrible by certain muscles which are not found in man. They are muscles which draw the eyelids backward upon the prominent eyeball, thus producing a fixed staring of the eye, and exposing its brilliant white coat, which by reflecting the light gives the eye a sparkling appearance. These muscles Sir Charles Bell calls *scintillantes*, from the apparent scintillating effect which they produce. In the cat tribe light is reflected from the bottom of the eye, when the pupil is dilated so as to admit the light over a large portion of the retina. This occurs in an obscure light simply because the pupil is then so much dilated. The light is not created in the eye, and it is no indication of passion, as has been supposed.

348. You have seen the fact most fully illustrated in this

chapter, that it is from combinations of action among the muscles, that the various expressions of the countenance result. To produce each one of these combinations, there must be a consent of action between the muscles. Some are relaxed, while others are contracted; and those which are contracted are in different degrees of contraction. Sometimes this harmony of action is sportively destroyed by one who has great command over the muscles of the face, and the most incongruous expressions result, mingled together in the same countenance, giving it a very ludicrous appearance. And I may remark, that the portrait painter is not always true to nature, but sometimes fails to depict the full harmony of muscular action in the expression of the countenance. I have noticed some of the combinations of muscular action in expression; but the view which you thus get of them gives you but a faint idea of the infinite variety of expression of which the human countenance is capable, as the result of these combinations. In order to obtain some adequate idea of this variety, keeping the views presented in this chapter in your mind, watch some one engaged in speaking or in conversation, in whom the play of the muscles of expression is peculiarly free. By so doing you will acquire new views of the capabilities of the countenance in communicating thought and feeling, and you will learn a lesson in this respect which the deaf mute from necessity learns every day.

349. But we do not get a full view of the combination of muscular action in expression, if we confine our observations to the countenance. As I remarked in the first part of this chapter, the muscles of other parts of the body, and sometimes of the whole frame, are brought into action in connection with the muscles of the face, in expressing thought and feeling. The attitudes and motions of other parts of the body correspond with the attitudes and motions of the countenance, so as to produce an harmonious effect. The hand is more used than any other part in aid of the countenance in expression; but the whole body is often brought more or less into action. The character of a passion can sometimes be inferred from the attitude merely, or from the mode of walking, as you see one at a distance.

> "You may sometimes trace,
> A feeling in each footstep, as disclosed,
> By Sallust in his Cataline, who, chased
> By all the demons of all passions, showed
> Their work even by the way in which he trode."

350. But it is the muscles of the respiratory organs which sympathize most with the muscles of the face in expression. This sympathy is the result of a nervous connection, and the nerve of expression in the face is therefore, as before stated, sometimes called the respiratory nerve of the face. Observe the prominent agency which the muscles of the chest have in the decided expression of the passions and feelings. In laughing the individual draws in a full breath, and then lets it out in short interrupted jets, the muscles of the throat, neck and chest, especially the diaphragm, being convulsively agitated. And if the laughter be strong and continued, he holds his sides, which become really sore, from the violent action of the respiratory muscles in this expression of his emotions. In weeping too, these same muscles are affected. The diaphragm acts spasmodically, the breathing is cut short by sobbing, the inspiration is quick, and the expiration is slow, and often with a melancholy note. But it is not alone in these marked cases that the respiatory muscles are seen to act, but you can observe their action in many of the slighter expressions of feeling.

351. There are certain effects produced by emotions upon the circulation, which heighten the expression resulting from muscular action. I have already referred to the blush of modesty, and the paleness of fear. In both laughter and weeping the spasmodic action of the muscles of respiration impedes the flow of blood through the lungs; and hence the countenance becomes flushed or suffused with the blood of the impeded circulation. This is very different from common blushing, which has nothing to do with the state of the general circulation, but is entirely a local effect, confined to the capillaries of the part, where it occurs. These capillaries are affected by the emotion through nervous connections, just as the minute secreting vessels in the tear glands are excited to unusual action.

352. From the views which I have presented of the capabilities of the human countenance in expression, you must be as much struck with its adaptation to the mind that moves it, as you were with the hand in this respect. Both are instruments of the mind, by which it accomplishes its purposes; and they would be out of place in any other animal, even one of a higher order, because he has not a mind capable of using such instruments to advantage. Man needs the face, with all its endowments, to express his thoughts and feelings, and the hand to do the handiwork which his mind designs; and the Creator has

proportioned the capabilities of these instruments to the necesities and the mental powers of man.

353. As the muscles of the face perform such high functions, as the instruments of the mind in expression, it is important that they should be well trained in these functions. Much is often said about the importance of grace in the attitudes and movements of the body, while seldom is a thought given to the attitudes and movements of the countenance. Muscles are at work in the one case as well as in the other, and the muscles of the face can be trained to work skillfully and gracefully as well as the muscles of any other part of the body. Indeed, grace of action is much more important in the face than in the body generally, because the muscles there are used so much more for expression than in any other part. And yet the speaker, who aims to gesture gracefully with his arms, is often very careless in regard to the gestures, for so we may call them, which are made by his face. So too the parent, who takes unwearied pains to make the gait and attitudes of her child graceful, often allows most uncouth attitudes of countenance to grow into a habit. Many a child that has been drilled most faithfully, in order to overcome awkwardness of movement, is suffered to become incurably awkward in the face, as some one has aptly expressed it. Sometimes even a habit of making grimaces is unconsciously contracted, which utterly prevents the countenance from accompanying the words that are uttered with any thing like appropriate expression.

354. Beauty depends much upon the attitudes and movements of the face, and not alone upon the shape of the features. We often see a face which is beautiful in repose, that becomes ugly the moment that it is in action, because the movements of the muscles are so ungainly. And, on the other hand, we often see faces which are quite at fault in the shape of the features, display great beauty when in action, from the movements which play so easily and gracefully among the muscles. It is a great triumph of the spiritual over the physical, when the mind within thus puts its impress of beauty upon a material form which is destitute of symmetry. When it does this, there is more to challenge our admiration, than when the sculptor chisels the marble into beauty. And if he were to undertake, in imitation of what we often see in living nature, to put beauty into ill-shapen features, he would signally fail. This can be done only by the active mind within, moving plastic features by the subtle agency of nerves and muscles. In relation to the inadequacy

of mere symmetry of form to meet our ideas of beauty in the living countenance, Addison has justly said, "No woman can be handsome by the force of features alone, any more than she can be witty only by the help of speech."

355. There is nearly as much difference in skill in the use of the muscles of the face, as in the use of those of the hand. And we need not go to the accomplished orator or actor, as furnishing us alone with the higher examples of this skill. It is often seen exhibited in the ordinary intercourse of life, in those who have great capacity of expression, together with a mind uncommonly refined and susceptible. In them every shade of thought and feeling is clearly and beautifully traced in the countenance. While this is the result of education of the muscles of expression, an education of which the individual is for the most part unconscious, no direct attempt in the training of these muscles will succeed, unless the mind itself be of the right character. Intelligence and kindness cannot be made to beam from the countenance, if they do not exist in the moving spirit within. They are often awkwardly counterfeited, the one by the bustling air assumed by the face of the shallow pretender, and the other by the smirk of him who smiles only to get favor or profit from others. The counterfeit is often mistaken for the reality ; and in relation to the truly intelligent and kind, there is often much error in the estimate put upon their intelligence and kindness, from the different degrees in which these qualities, when existing in the same amounts, are exhibited in the expression of the countenance. In some, the muscles of expression respond more readily and aptly to the thought and feeling within, than they do in others.

356. I know not of any more beautiful and striking exemplification of the influence of the mind and heart upon the expression of the countenance, than is to be seen in those institutions where juvenile outcasts from society are redeemed from their degradation by the hand of benevolence. You can often note most clearly the progress of the mental and moral cultivation in the lineaments of the face, as lively intelligence takes the place of stolid indifference, and refined sentiment that of brutal passion. Sometimes a few weeks suffice to change the whole character of the expression. The dull eye becomes bright, not from any change in the eye itself, but from the intelligence and sentiment which now play upon the muscles in its neighborhood. Those muscles which impart a lively and pleasant cast to the countenance when they are in action, are awakened from their

long continued dormant state by the magic wand of benevolence, and thus give outward expression to the thoughts and feelings, which genial influences are producing in the mind and the heart. The change is often as great in a little time, as it would be in the face of an idiot, if he could be suddenly brought into the full possession of the mental faculties.

357. The habitual expression of the countenance, depending as it does upon the habitual condition of the muscles, is seen after death. In the state of relaxation which immediately occurs at death the face is very inexpressive, because its muscles are, together with those of the whole body, so entirely relaxed. But very soon they begin to contract, and they assume that degree of contraction to which they were habituated during life, and therefore give to the countenance its habitual expression. It is when this has taken place—when the muscles, recovering from the relaxation of the death-hour, resume their accustomed attitude, as we may express it, that the countenance of our friends appears so natural to us, and we are held, as if by a charm, gazing upon the intelligence and affection beaming there amid the awful stillness of death, till it seems as if those lips must have language. And this expression is retained through all the period of rigidity, till it is dissolved by the relaxation which succeeds this state and ushers in the process of decay. It is thus that the soul, as it takes its flight, leaves its impress upon the noblest part of its tabernacle of flesh; and it is not effaced till the last vestige of life is gone, and the laws of dead matter take possession of the body. The state of countenance which I have described is thus beautifully alluded to by Byron.

> He who hath bent him o'er the dead,
> Ere the first day of death has fled,
> The first dark day of nothingness,
> The last of danger and distress,
> (Before decay's effacing fingers
> Have swept the lines where beauty lingers),
> And mark'd the mild angelic air,
> The rapture of repose that's there,
> The fix'd yet tender traits that streak
> The languor of the placid cheek,
> And—but for that sad, shrouded eye,
> That fires not, wins not, weeps not, now,
> And but for that chill, changeless brow,
> Where cold obstruction's apathy
> Appals the gazing mourner's heart,
> As if to him it could impart
> The doom he dreads yet dwells upon;
> Yes, but for these, and these alone,

Some moments, aye, one treacherous hour,
He still might doubt the tyrant's power;
So fair, so calm, so softly sealed,
The first, last look by death revealed!

CHAPTER XIV.

THE VOICE.

358. The apparatus of the voice is truly a musical instrument. We can see therefore, in its construction and arrangement, the application of those principles, which usually regulate the production of musical sounds, and which man observes in making the various instruments which his ingenuity has invented to delight the ear. It is, however, a much more perfect instrument than any which man has invented. Almost every musical instrument, it is true, has a greater compass than that of the human voice; but it is by no means the chief excellence of an instrument that it can command a great extent of the scale. The apparatus of the voice can execute enough of the scale for all common purposes. It is wonderful that its compass is so great as it is, for it is a very small instrument, occupying a space of less than an inch square where the vibrating ligaments are situated. In every respect besides compass this instrument far excels all others. Listen to a good voice which has been well educated. Its transitions have an ease and a grace which the workmanship of man can not equal; the richness and sweetness of its tones are above all imitation with the most perfect instruments; and utterance is given to its various notes with so little apparent effort, with so little show of machinery, in comparison with the instruments made by man, that we are filled with wonder at the effects produced by so simple, delicate, and beautiful a piece of mechanism. But the most important circumstance to be noticed is, that there are parts connected with this apparatus, which give *articulation* to the voice as it comes from the vocal chords, thus making it the principal medium of communication between man and man. This distinguishes it from every other musical instrument, and constitutes

its crowning excellence. When I come to speak particularly of the articulation of the voice, you will see how really complicated is the apparently simple mechanism that produces the varied articulations, and thus makes the voice the chief medium of mental communication. And if you try to measure, with the utmost stretch of conception, the endless variety of thought and feeling, which this apparatus conveys daily, hourly, every moment from heart to heart in the intercourse of life, you will be able to estimate in some good degree the value of those organs, which, though we seldom spend a thought upon them, are so constantly ministering to our enjoyment.

359. Such being the high uses for which the voice is designed, when it possesses a rich and flowing melody, and its articulation is graceful and easy, its powers of fascination are wonderful. Such a voice is a fit medium of communication for "thoughts that breathe and words that burn." This is more often true of the voice of conversation than that of song. It is in the hourly intercourse of life that melody of voice is most valuable to us as a source of enjoyment, and here its influence is often astonishing. It will sometimes give a charm, not to say beauty, to an ordinary face; while on the other hand, the fascination of beauty is often destroyed by the utterance of a voice harsh and without melody. And it may be remarked that a rich and finely modulated voice of conversation, and a melodious voice of song, do not always go together. The voice which has delighted the ear of multitudes at the public concert, may be divested of all its charms, when used in conversation; and on the other hand, there are many who sing unskillfully, and yet in conversation give utterance to genuine and varied melody.

360. There is music not only in the human voice, but in the voices also of the brute creation. And the varied forms of the apparatus by which it is produced show the impress of the same power. What variety there is in the sounds which come from the multitudes of different animals on our globe, and how diversified is the handiwork exhibited in their vocal organs! The power from which springs this endless variety is the same as that which gives such diversity to the human countenance, and I know not which is the most wonderful display of it. And it may be remarked, that although the voices of some animals are harsh and discordant, those which we most frequently hear are melodious. Even some of those which are unpleasant to the ear, become in some degree pleasant when occasionally heard at the right time and in the right place, from the addition which

they make to the variety of sounds that we hear, and from the associations which become connected with them. A goose on a common, says Cowper, is no bad performer.

With these preliminary remarks I proceed to the investigation of the subject. I shall speak first of the voice as it is produced in the larynx by the vibration of the vocal chords or ligaments, and then treat of the articulation of the voice.

361. As the apparatus of the voice is really a wind instrument, I will first develope the principles on which wind instruments produce the various musical notes, and then show you the resemblance between these instruments and the set of organs which are engaged in producing the notes of the voice. Wind instruments are of two kinds—those that have an inflexible mouthpiece, and those in which the sounds are produced by a vibrating reed. The horn, trombone, trumpet, flute, fife, flageolet, flute-stop and other stops of the organ, &c., are instruments of the first kind. The cause of the variation of notes produced in these instruments may be thus explained. The column of air contained in the tube is the vibrating body from which proceeds the sound. Any thing then that affects the column of air affects the note. The length, the breadth, and the mode of producing the vibrations are the causes of the variation of the note. The holes which are in the side of a flute are for the purpose of altering the length of the confined column of air. In the trombone this is done by sliding one part of the instrument upon the other. The general rule is, the longer is the column of air the more grave is the note. Thus in the flute, the lowest note that can be produced by the instrument is made by covering all the holes, so that you have a column of confined air the whole length of the tube. The highest note, on the other hand, which the instrument is capable of producing is made by so arranging the fingers as to allow the air to escape at the first hole. In this case the length of the confined vibrating column of air extends only from the mouth

FIG. 135.

hole to the hole from which the air escapes. I take another illustration from the organ. Fig. 135 is a representation of one of the pipes of the flute-stop of the organ, which is a wooden box, made very much after the manner of a boy's chesnut whistle. At *a* is the passage for the introduction of the air; *b* is the inclosed column of air, the vibration of which produces the sound; *c* is the place of escape for the air; and *d* is a movable plug, by means of which the vibrating column of air can be made longer or shorter, according to the note desired. In tuning the organ, if the pipe gives too low a note the plug is moved downward, thus shortening the column of inclosed air, but if too high a note, the plug is raised up.

362. The same rule applies to the *width* of the vibrating column of air. The wider the column the graver the note, and vice versa. I would observe, that in a long, slender column of air, as in the trombone, by giving the current of air from the mouth a great velocity a high note may be produced; but where, as in the ophicleide, the column is both wide and long, it is difficult to do this, because it is difficult to produce a quick vibration in so large a body of air, with all the suddenness and force with which we can move it.

363. In those instruments which have no expedient for altering the length of the column of air, such as the common horn, the various notes are produced by narrowing or widening the orifice by the agency of the lips, as the case requires, at the same time giving, by the varied velocity with which the air is forced into the instrument, a quicker or slower vibration to the air. Grave sounds are produced by a wide, and acute by a narrow opening. In playing the flute the opening of the lips is thus varied in order to produce a vibration which shall correspond with the length of the column of air. If the flute player, with his fingers arranged for a high note, should blow into the mouth hole with his lips forming a large orifice, he would not produce the desired note. To produce the proper vibration in a short column of air, the orifice from which the air issues to move this column must be small enough to correspond, and with it there must be the requisite velocity in the air as it comes from the mouth. You have a good illustration of the influence of size of orifice on the note of sound in common whistling. The higher the note produced the more narrow is the outlet from the mouth. The size of it is regulated by both the lips and the tongue.

364. In *reed* instruments the variations in note are produced

in a different manner. The clarionet, hautboy, bassoon, the reed stops in the organ, &c., are instruments of this sort. It is the vibration of the thin plate called the reed that causes the sound. The longer this plate is, the slower are the vibrations, and therefore the graver is the note, and vice versa. The principle can be well illustrated in the reed stops of the organ. The reeds in the different pipes are made of different lengths, according to the notes which they are to produce. In a reed instrument played by the mouth, as the clarionet for example, the rapidity of the vibrations is regulated by the pressure of the lips. In producing a high note the lips press firmly on the reed and leave but a small portion of it to vibrate; while in producing a low note the lips press less firmly on the reed, and leave a large portion of it to vibrate.

365. You see that the same principles apply to the reed as to the column of air in the other kind of wind instruments. In both cases the longer and thicker the vibrating body the coarser is the vibration, and the graver the note. This same principle also applies to stringed instruments. Thus in the piano, the grave notes come from long and large strings, while the higher notes come from slender and short ones. In the violin the strings are all of the same length, the larger strings giving the graver notes, and the smaller the higher ones. The notes are varied also in the case of each string, by varying the tension. They are varied too while playing on the instrument by varying the length of the vibrating strings by the pressure of the fingers.

366. The reed is always connected with a tube. Has this any influence upon the note produced by the reed? It contains a column of air through which the sound caused by the vibration of the reed must pass. Unless, then, the vibration of this column of air corresponds with the vibration of the reed, it will alter the note. It does alter the note to some extent always. It never raises it, but always makes it more grave. That is, the vibration, in passing from the reed to the column of air, becomes less rapid and coarser, as is always the case when vibration passes from any substance to another. But the tube is so arranged that there may be as little change in this respect as possible, and yet have the combined effect of a reed and wind instrument secured. Holes are therefore properly placed in the side of the tube, so that with the fingers the column of confined air may, in the case of every note, be placed in correspondence with the vibration of the reed. Suppose the tube to be long and without holes; in this case low notes could be easily pro-

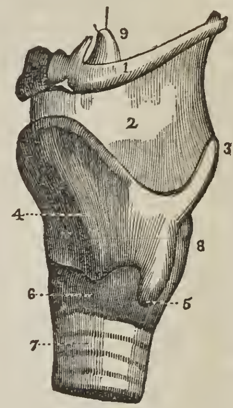
duced, but attempt a high note and you would fail. The reason is obvious. The low note is caused by a low and coarse vibration of the reed, for the transmission of which a long column of air is fitted. But if a high note be attempted, the slow vibration of the long column of air *disagrees* with the quick vibration of the reed, and flattens very much the sound after it comes from the reed, as it passes through the tube. As I have already hinted, the object of the tube is to secure in the instrument the combined effect of a reed and a wind instrument. The tube makes the reed speak, as it is expressed; that is, it gives intensity and an agreeable character to the sound. If you disconnect the reed of the hautboy or bassoon, for example, from its tube, and blow upon it, you can produce all the variety of notes, but the sound is disagreeable; but by connecting the tube with the reed you produce a *compound* sound, as we may call it, which has a sweet and rich melody.

We will now examine the apparatus of the voice, and see how far the principles which I have developed in relation to common musical instruments are applicable to this instrument.

367. Just at the root of the tongue, as described in the Chapter on the Bones, § 282, is a small bone, shaped so much like the Greek letter *v* that it is called the *hyoid* or U-like bone. The round end of this bone is towards the root of the tongue, and its two ends point backward toward the pharynx. To this bone is connected a long cartilaginous tube extending to the lungs, called the trachea, or windpipe. It is through this tube, as you have already learned, that the air goes back and forth from the lungs in respiration and speech. It is not one solid tube, but is composed of a great number of rings of cartilage connected together by membranous parts. The rings are not perfect circles. They are deficient behind, and this deficiency is supplied by a membrane. The object of this arrangement is evident. The part of the tube where the rings are deficient is directly in front in its whole length of the œsophagus or gullet, the tube through which the food passes. If the rings had been made entire, it is manifest that their pressure would interfere somewhat with swallowing. But it is the *upper* part of the windpipe, that part which is immediately below the U-like bone, which claims our attention as the seat of the formation of the voice. This part is called the *larnyx*. It is formed of five cartilages, the arrangement of which I will now show you. The largest of these cartilages, the one which forms the most of the body of this music-box, as we may call it, is the *thyroid*. It is

the *pomum Adami*, or Adam's apple, which is so easily felt in the top of the neck. This cartilage forms the front and sides of the larynx, but it is open behind. The cricoid cartilage is shaped very much like a seal ring, and this resemblance gives it its name. The narrow part of it is situated directly under the thyroid cartilage, in its front and at its sides, but the broad, seal-like part of it is behind, projecting upward and filling up a part of the open space left by the deficiency of the thyroid in in its rear. A side view of these parts is given in Fig. 136, in which 1 is the the U-like bone; 4 is the thyroid cartilage; and 6 the cricoid. At 8 is the back part of the cricoid, filling up a part of the space in the open rear of the thyroid; 3 is a horn shaped projection of the thyroid, and 5 is a smaller one below, projecting over on to the outside of the cricoid; 2 is a strong membrane or ligament connecting the hyoid or U-like bone with the top of the thyroid; 9 is the epiglottis, drawn up by a hook; and at 7 are the rings of the trachea. The epiglottis is composed in part of cartilage. It is, as I have already told you, in the Chapter on Digestion, § 78, the lid of the music box, the larynx, shutting down when we swallow, so that the food or drink may pass over it, and being raised up when we breathe or speak.

FIG. 136.



Side view of
THE LARYNX.

368. There are two small cartilages which are not seen in this figure, called *arytenoid* cartilages, from two Greek words, meaning *ladle* and *shape*, because they bear some resemblance in form to a ladle. They stand in the open space in the rear part of the thyroid, on the top of the cricoid cartilage. They are the pillars to which the vocal chords or ligaments are attached behind. These two cartilages are movable, having a regular joint with the upper edge of the cricoid. There are small muscles which pull them in different directions, and thus change the degree of tension and the position of the vocal ligaments, and of course vary the note of the sound produced by their vibration. That you may understand how this is done, I give you

in Fig. 137 a diagram showing the arrangement of these ligaments. It represents a view of them as you look *down* into the larynx, in which *a* is the front of the thyroid cartilage, and *bb* are the two arytenoid cartilages. To these you see are attached two sheets of membrane, which are also fastened all around to the inside of the thyroid. If these movable parts, as we may call them, to which the ligaments are thus attached, be drawn backward, it is obvious that it will make the ligaments more tense. If they are separated from each other, the opening between the ligaments will be widened. If they are brought nearer together, this opening will be narrowed, and the forward part of the free edge of each ligament will be prevented from vibrating, because it is here brought in contact with the other ligament.

FIG. 137.

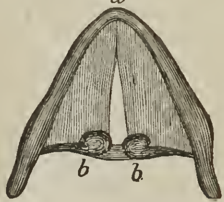
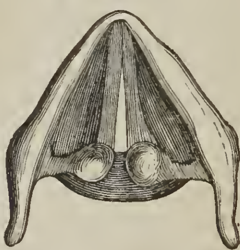


Diagram showing the action of the VOCAL LIGAMENTS.

Now there are small muscles which are attached to the arytenoid cartilages for the purpose of moving them as I have pointed out. The figure which I have presented is a mere diagram, to show the arrangement of the ligaments for the production of the various notes of the voice. In Fig. 138 is represented the actual appearance of the ligaments and the arytenoid cartilages, as you look down upon them. The ligaments you observe are thicker at their free edges than any where else.

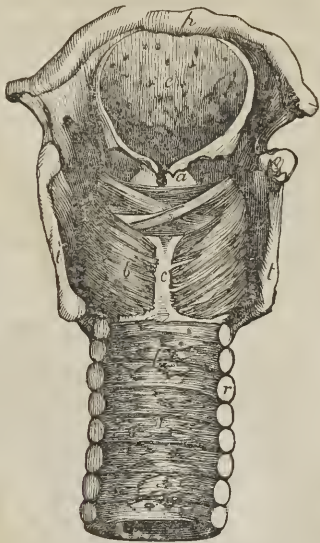
FIG. 138.



THE VOCAL LIGAMENTS.

369. In Fig. 139 you have a view of the larynx and trachea from *behind*, in which are shown two of the muscles that move the arytenoid cartilages. At *h* is the hyoid bone; *t t*, the posterior margins of the thyroid cartilage; between these stands the broad rear part of the cricoid cartilage, the middle line of which you see at *c*; at *r* are the rear ends of the rings of the trachea; *l* is the membranous part of the trachea, which lies in front of the œsophagus or gullet; *a* marks the top of one of the arytenoid cartilages, and you see also the top of the other; *e* is the epiglottis represented as

FIG. 139



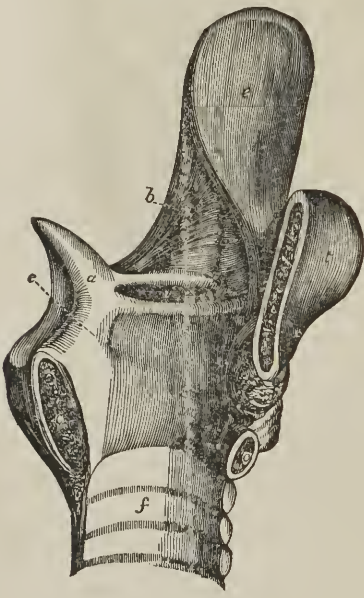
REAR VIEW OF THE LARYNX AND THE TRACHEA.

raised up as when we are speaking; *b* is a muscle, which, beginning at the middle line of the cricoid cartilage, runs forward, and is fastened to the outside of the arytenoid cartilage, there being one like it on the other side, as you see; *s* is another muscle going from the cricoid to the arytenoid cartilage, which also has its fellow on the other side. You can see that the muscle, *s*, and its fellow, if contracted would bring the arytenoid cartilages nearer together, and so diminish the opening between the vocal membranes which are fastened to these pillars. The muscle, *b*, and its fellow, on the other hand, when they act, so draw upon the outer edges of the arytenoid cartilages as to separate these cartilages from each other, and therefore enlarge the openings between the ligaments. There are other muscles not seen in the figure, that alter the size of the orifice between the vocal ligaments and their degree of tension, and thus affect the notes of the voice.

370. I have described the true vocal ligaments. But there

is another pair of ligaments directly above them, the space between which is the real opening into the larynx, upon which the epiglottis shuts down when we swallow. You will get a good idea of the arrangement of the two pairs of ligaments from Fig. 140. This is a representation of an *inner* view of one

FIG. 140.

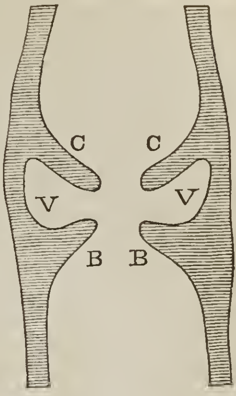


INTERIOR OF THE LARYNX.

half of the larynx, the division being made directly down, and from front to rear. At *t* is the front of the thyroid cartilage with its cut edge; at *c c*, are the two cut edges of the cricoid, showing how narrow is its front part compared with its broad rear portion; *a* is the left arytenoid cartilage, *c* showing the place where it is united by a joint to the top of the cricoid; *f* is the trachea; *r* is the true vocal ligament or chord; *v* is the space between this and the upper ligament; and *e* is the epiglottis which is shut down upon the upper ligaments as a cover by the contraction of the muscle *b*, just when this is needed.

In Fig. 141 is a diagram representing the plan of these two pairs of ligaments, as shown by a perpendicular section from side to side. B B represents the vocal ligaments, C C the upper ligaments, and V V, the two recesses between them.

FIG. 141.



371. We know that it is the lower ligaments that are the true vocal chords, because the parts above these, even the upper ligaments, may be all cut away, and yet a vocal sound may be produced; while if an opening be made into the larynx below the lower ligaments the voice will be destroyed. Magendie, a French physiologist, speaks of a man, who on account of an opening in the larynx was never able to speak without pressing his cravat tightly against this opening, in order to prevent the air from escaping through it. Many experiments have been tried with the larynx after death to verify the results above stated. The lower ligaments are then the vocal chords, by the vibration of which all the different notes of the voice are produced. And the other parts of the vocal apparatus serve only to modify the sound caused by the ligaments. The lungs act merely as the "wind-chest," to hold the air which being forced out strikes on the ligaments, and makes them to vibrate.

372. Let us now apply to this apparatus the principles which I have developed in the beginning of this chapter, as regulating the variation of note in common musical instruments. The size of the aperture, through which the sound is thrown out, influences the note, of which we have a familiar example in whistling. And as you have seen that the size of the opening between the vocal ligaments is varied by the muscles moving the arytenoid cartilages, this must have an influence upon the note of the voice. But this is not the only cause of the variation of the note. As I showed in relation to the reed, and to the strings of stringed instruments, so also here the larger and less tense are the vibrating bodies, the vocal chords, the graver is the note, and vice versa. You have seen

how these chords or ligaments are varied in tension by the action of the muscles that move the arytenoid cartilages. You have also seen that, as these cartilages are brought near together by the muscles, the extent of the free vibrating edges of the ligaments is shortened, because their edges are brought together in their anterior part (Fig. 137). Magendie verified this by observation. He opened the throat of a noisy dog in such a way that he could look directly upon the vocal ligaments. When the sounds were grave, he observed that the ligaments vibrated in their whole length, and that the air passed out in the whole length of the chink between them. But when the sounds were on a high note, the ligaments did not vibrate in their anterior part, but only in the posterior, and the air passed out only at the open vibrating part. It is manifest that in producing the various notes, the muscles that move the arytenoid cartilages act upon the ligaments just as the lips do upon the reed of the hautboy or bassoon, regulating the extent and the rapidity of the vibrations.

373. There has been much discussion as to the kind of musical instrument the larynx most resembles. From the facts above stated it appears clear that it most resembles reed instruments, though its analogy to stringed instruments is also quite apparent. There is also a resemblance to some small extent to common wind instruments, as the size of the orifice between the vocal ligaments must have some influence upon the note. Whatever we may think as to the degrees in which these analogies exist, we can see that the great principle of musical sounds is regarded in all the arrangements of the vocal apparatus, viz., that coarse and slow vibrations produce grave notes, while rapid and fine vibrations produce high ones.

374. I will trace the resemblance between the instrument of the voice and common musical instruments still farther. The sound as it comes from the larynx passes through a tube, just as the sound coming from a reed does in a reed instrument. In other words there is a body of inclosed air extending from the larynx to the outlets of the mouth and nose, which vibrates in transmitting the sound from the larynx. This body of air is not as simple in its form as that is which is inclosed in the tube of common reed instruments. It has three outlets, the mouth and the two nostrils. The sound of the voice, however, seldom comes out from the orifices of the nostrils, but almost always from the mouth. In humming it comes altogether from the nostrils. In ordinary speaking and singing the cavities of the

nose act as reverberating cavities, the sound which reverberates there issuing from the mouth. This fact will be illustrated when I come to speak of the articulation of the voice. The curtain of the palate answers as a sort of swing door between the cavity of the mouth, and the cavities of the nose, to direct the air the one way or the other. When a sound is to be reverberated in the cavities of the nose, it hangs in such a way that the communication between the mouth and these cavities is open.

375. You have seen that the tube connected with the reed in the reed instrument is so arranged, that the length of the confined column of air can be changed, in producing the different notes, the vibration of the air thus being brought into correspondence with that of the reed. How is the same thing effected in the vocal apparatus? It is done in two ways. First, the length of the tube is altered. If you place your finger on the front of the larynx, and then sound various notes, you will feel the larynx rise when you sound a high note, and fall when you sound a grave one. The object of this movement is to alter the distance from the larynx to the outlet of the mouth, in other words, to alter the length of the column of air in the tube, so that it may correspond in its vibration with the vibration of the vocal chords. But the size of this column of air is altered in another way. It is altered in its *width*, which, as I have remarked in relation to musical instruments, § 362, is quite as effectual in changing the vibration as an alteration of length. The tube of the vocal instrument you readily see can be altered in its width by the muscles of the throat and mouth.

376. The object of the tube of the reed instrument is, I have stated in § 366, to make the reed speak, as it is termed; that is, to give intensity and an agreeable character to the sound. The tube in the instrument of the voice undoubtedly does the same thing. If the voice should come directly from the larynx without passing through the tube attached to it, it would be as disagreeable as the sound of a reed when separated from its tube. The voice gets most of its melody after it is made in the larynx, as it passes out through the column of air in the throat and mouth. And it is the variations of this tube produced by the muscles that surround it that give to the voice its variety of tone as well as its melody, thus constituting one of the great excellencies of the vocal instrument in comparison with all common musical instruments. If the voice of Jenny Lind

could be made to come directly from the larynx, notwithstanding its great compass, it would lose all its charm, and would be better fitted for the performances of Punch and Judy, than for the public concert.

377. It is a very common popular notion, that a hoarseness, or a loss of voice, indicates disease in the lungs. But you have seen that the lungs are the mere bellows, or the "wind-chest" of the organ of the voice, and that the voice is produced by the vibration of the vocal ligaments as the air forced from the wind-chest strikes them, and is modified by the tube which extends from the larynx to the outlet of the mouth. Any alteration of the sound therefore, as hoarseness, must be caused by difficulty either in the ligaments, or the tube, or in both, and an entire loss of the voice can be caused only by an affection of the ligaments. Disease in the lungs, it is true, is very apt to affect the larynx and the throat by extension or by sympathy, and thus alter the voice; but it often does not. Consumptive persons sometimes have a clear voice almost to the last.

378. The epiglottis, besides acting as a lid for the larynx, for the food to pass over it into the œsophagus, also has an influence upon the voice in two ways. First it can be made to narrow more or less the passage of air from the larynx. And secondly, some experiments of M. Greniè on reed instruments show, that it has an influence upon the intensity of the voice. When experimenting on some reed instrument, he wished to increase the intensity of sound without changing the reed. For this purpose he gradually increased the force of the current of the air; but this not only augmented the sound, but raised its note. He at length obviated the difficulty, by placing obliquely in the tube, just under the reed, a supple elastic tongue. He could now give greater intensity to the sound without raising its note. The epiglottis seems to perform the same office in our vocal tube, for it is elastic and supple like the little tongue which M. Greniè placed in the tube of his instrument. Its situation is similar also, it being directly over the double reed of the larynx, as we may call its ligaments. There are muscles to move it, so that it may be at the right inclination in all cases. One of these is seen in Fig. 140 at *b*.

379. I have thus traced the analogy between the apparatus of the human voice, and musical instruments. How nicely adjusted are all its parts! With what precision must the muscles that move them act in those who are able to produce the most delicate, as well as the most striking variations of note! Every

modulation of the voice, however slight, requires muscular action to effect it. The vocal ligaments must be put in just such a state, or the wrong sound will be produced. So too, the muscles of the mouth and throat must put the tube of the vocal instrument into the right shape, in order to have the contained column of air correspond in vibration with the vocal ligaments. To have some conception of the variety of the motions of the muscles concerned in the modulation of the voice, listen to some singer whose voice can command with ease and freedom a great extent of the scale. For every note that you hear there is a distinct and particular adjustment of the vocal ligaments, and of course a particular degree of contraction of the little muscles that move them. Let us see how delicate the action of these parts is. It is calculated that the ligaments vary in length only about the $\frac{1}{5}$ of an inch in producing all the notes of the voice. Now the natural compass of the voice (that is its range from its lowest to its highest note) in most singers is about two octaves or 24 semitones. Within each semitone a singer of ordinary capability can produce 5 or 6 distinct notes; so that for the whole number of notes that he can sound distinctly 120 is a moderate estimate. He therefore produces 120 different states of tension in the vocal ligaments. And as the variation in their length for passing from the lowest of these 120 notes to the highest is only the $\frac{1}{5}$th of an inch, the variation required to pass from one note to another will be only the $\frac{1}{600}$th of an inch. A very expert singer can produce a much more delicate action than this, and distinctly appreciate the result by his ear. How great the contrast between the minute contractions of the little muscles that move these vocal ligaments, and the contractions of the large muscles in the arm that wield the ax and the sledge-hammer!

380. It is proper to notice here one very marked difference between the vocal apparatus and common musical instruments. I have spoken in the previous paragraph of distinct notes as executed by the voice. Most instruments execute only these distinct notes. But the voice can also glide from one note to another with a continuous sound. In this respect the vocal instrument is superior to common musical instruments. There is one instrument, however, the violin, in which this gliding movement can be to a great extent imitated. It is done by sliding the finger on the string, as it vibrates under the bow. A peculiar use of this gliding movement distinguishes the voice of speech from that of song, as I shall show you in another part of this

chapter. It is by an imitation of this, by sliding the finger on the string, that the violin can be made to imitate so well the tones of conversation.

381. The muscles, by which all the variations in the tension of the vocal ligaments are effected, receive nerves from the brain, and are under the guidance of the will. When the mind therefore wills to produce a certain sound, these muscles immediately place the parts in such a state as to cause that sound. This is true of the muscles that put the tube in correspondence with the larynx, as well as of those which produce the right state of tension in the ligaments. It is also true of the muscles which articulate the voice, of which I am yet to speak, and of those which work the chest, the bellows or "wind-chest" of the organ of the voice. The muscles of this apparatus are in the same condition with other voluntary muscles; and therefore, like them, the more they are trained in the exercise of their powers, the more perfect will be their action. The muscles in the arm and hand of the infant learn to execute the motions of which they are capable gradually. Just so it is with the muscles of the voice—from our infancy they are trained under the ear as an instructor. The muscles which regulate the adjustment of the vocal ligaments, in producing the different notes, cannot do it accurately without the education of exercise, any more than the lips of one just beginning to play on the hautboy or clarionet, can regulate their pressure on the reed, so as to sound the different notes correctly. The analogy is perfect, for it is the *muscles* moving the vocal chords that vary the note of the voice, and it is the *muscles* moving the lips that vary their pressure on the reed, and of course vary the note of the instrument.

382. The skillful singer or speaker exhibits much skill in managing the muscles of the "wind-chest." He keeps it all the time well supplied with air, so that but a comparatively slight action of the expiratory muscles will suffice to throw the air against the vocal ligaments with the requisite force. But an unskillful singer or speaker much of the time has his chest poorly supplied with air, and so speaks or sings, as it is expressed, from the top of the chest. It costs him, therefore, so much labor to throw out the air with sufficient force, that he is soon tired out. The necessity of keeping the chest full of air, in order to work the vocal apparatus easily, may be illustrated by reference to the bagpipe. If the bag containing the air be well filled, a slight pressure of the arm upon it will force the air through the pipe with sufficient rapidity to produce the sound. But if the

bag be flaccid, from the little quantity of air in it, a very strong pressure of the arm will be required to produce the same effect.

383. But it is not the muscles of the chest only that are tired out in the unskillful singer or speaker, but also the muscles of the larynx and the throat. And a frequent tiring of these muscles weakens the force of the parts, and often at length produces disease. Much of the throat-disease of public speakers comes from this cause, and is a nervous disease, the affection of the lining membrane of the throat being often a mere accompaniment. This result is more apt to occur when the nervous force of the system generally is impaired, than when there is a state of vigor. It is also more apt to occur in those who speak in a uniform and somewhat monotonous manner, than in those who have much variety in their mode of speaking. A continuation of precisely the same muscular effort for any length of time is apt to produce painful exhaustion, while a much greater amount of *varied* muscular effort may be put forth without weariness, or even with pleasure.

384. It would be interesting to trace the differences in the arrangement of the vocal apparatus in different animals, but I will only notice the arrangement which we find in birds. The voice of birds is formed not, as in us, at the top of the windpipe, but at its lowest portion. Like the human voice, it is produced by the vibration of sheets of membrane. These are placed just at the division of the trachea, where its two branches go off to supply the two lungs with air. The voice is formed by these ligaments, and is then transmitted through the column of air contained in the whole length of the windpipe. This column of air must have some influence on the note of the voice, according to its length and diameter. Birds, therefore, in singing different notes change its length in some measure. This is easily done, as the windpipe is composed of rings of cartilages, connected together by membranous substance. There are muscles indeed up and down the tube, for the purpose of shortening it by approximating these rings to each other. As the turkey gobbles he throws his head up and down, and thus shortens and lengthens the trachea. This movement is quite obvious also in the canary bird.

385. Having thus treated of the formation and the modulation of the voice, I come now to its *articulation*, which makes it the grand medium of intercourse between man and man. I will first describe the parts engaged in articulation, and then speak of the agency of each of them.

386. The vocal tube, which I have described as extending from the larynx to the outlets of the mouth and the nostrils, produces all the variety of pronunciation in all the different languages of our globe. It is all one cavity, though it is partially divided by partition walls. If you recur to Fig. 10, on page 48, you will see a representation of this compound cavity. At the top of the trachea *d* you see the epiglottis *c*, which shuts down upon its orifice when we are swallowing. Above this is a large space called the pharynx. It is the back part of the throat, which we can see behind the arch of the palate on looking at it through the open mouth. Its communication with the mouth and the cavities of the nose is regulated by the palate *g*, which is moved by muscles into the different positions required. The cavities are very complicated, having several partitions partially dividing them, as seen in Fig. 89, and they communicate with cells in the bones by small orifices. That very movable organ, the tongue, and the teeth and lips, I need not describe.

387. We will now observe the agency which the different parts of this compound vocal tube have in the articulation of the voice. Every letter, whether it be a vowel or a consonant, requires a particular position of the different parts of the vocal tube. In some letters the tongue is the chief agent in articulation, in others the lips, in others the teeth. in others the palate, and there are some in the formation of which the cavities of the nose have an important agency. I will notice the different parts separately.

388. The tongue has been considered so essential to speech, that tongue and language are often used synonymously. But though it does perform an important part in articulation, it is not absolutely essential. Though it assists in the formation of many of the alphabetical elements, it is the principal agent in but two of them, *l* and *r*. The loss then of this busy little organ does not necessarily produce dumbness, nor even impair to any great extent, in some cases at least, the power of speech. To prove this I will cite a few facts which appear to be well authenticated. The Emperor Justin says that he had seen venerable men who, after their tongues had been cut off at the root, "complained bitterly of the torture they had suffered." He says also in another place that some prisoners, who were punished in this barbarous manner by Honorichius, King of the Vandals, "perfectly retained their speech." But there are cases more thoroughly attested, having been examined and reported upon by scientific observers. A boy, who lost his tongue by disease at the age of eight years, was exhibited publicly because

he could talk without a tongue. At the request of the members of the University of Saumur, the boy was brought before them by his friends. After a strict examination they were perfectly satisfied as to the facts in the case, and recorded their official testimony to that effect. A very interesting account is given of another case in the Philosophical Transactions, in several papers published from time to time between the years 1742 and 1747. It is the case of a girl who lost from disease the whole of her tongue, together with the uvula, (the little round body which hangs down from the middle of the arch of the palate,) and yet could talk and swallow as well as any one. So perfect was her articulation, that she could pronounce with exactness those letters which commonly require the agency of the tip of the tongue. She could sing finely, articulating with the same clearness as when she talked. The sockets of the teeth too were so much injured, that there were few teeth, and these rose so little above the gums, that they could not render much assistance, if any, in articulation. This case was investigated very thoroughly. The account was given to the Royal Society, attested by the minister of the parish, a physician of repute, and another respectable person. The Society, not wishing to give too easy a credence to so strange a case, requested another report from another set of witnesses appointed by themselves, and they gave them a series of questions to guide them in their investigations. The report which they made out coincided very minutely with the account first given. The case excited so much interest that the young woman was at length brought to London, and appeared before the Royal Society to satisfy them that she could really talk and sing, although she had no tongue.

389. Some of the letters are formed principally by the teeth, as *c*, *t*, *s*, *z*. They are therefore called *Dentals*. It is the too frequent and bungling employment of some of these which constitutes lisping. Those who have a tongue too large for the mouth are apt to lisp. In advanced age, when the teeth are lost, we find this defect of lisping. The reason is obvious. When the teeth are gone, the sockets gradually become obliterated, and that part of the jaw-bone where the teeth were, of course diminishes in size, making the mouth too small for the tongue.

390. The letters, in the articulation of which the lips take the lead are *b*, *p*, *m*, *f*, *v*, *w*, &c, and are called *labials*. Children, when they first begin to talk, use labials freely, because they can see in others the motions necessary for their pronunci-

ation, and then imitate them. Hence the endearing terms used by the child to the parent are, I believe, in all languages, or nearly all, composed of labials and vowels. And too, it is from the delight which the child takes in repeating over and over these terms, that we have the word *papa* and *mama*, instead of *pa* and *ma*. The same thing can be observed in other languages as well as the English. If we teach a child to say father instead of papa, he finds little difficulty in articulating the first syllable, because it begins with a labial, *f;* but in the last syllable he will at first substitute for *th* the labial *v*, making it *fāver*. Intoxicated persons, their lips being weak and trembling, are apt to make an awkward use of the labials, as well as of those letters in which the tongue has much agency. Persons with large lips also are apt to use the dentals unskillfully. Sometimes one labial is used for another, as *f* for *v*, and *p* for *b*. This is very common among the Welsh. Shakspeare gives us an amusing case of this sort in Sir Hugh Evans in the Merry Wives of Windsor. "Ferry goot," says he, "I will make a prief of it in my note book." And so he says prains for brains, peings for beings, petter for better, &c. The labial *w* is sometimes used for *v*, thus, winegar, indiwisible, werry wigorous.

391. The nasal cavities, it is obvious, must have a great influence in articulation. The letters *m* and *n* are partly nasal. In pronouncing *m* at the end of a syllable, as *am*, *em*, or *om*, we close the lips, and the sound issuing from the larynx reverberates in the cavities of the nose. You can perceive this reverberation by pressing gently upon the nostrils with the fingers while pronouncing this syllable. The same can be said of *n*, except that in pronouncing it we press the tip of the tongue against the roof of the mouth just behind the front teeth, preventing the passage of the air out through the mouth in this way, instead of doing it by closing the lips, as in articulating *m*. When *m* and *n* begin syllables, as in *mo* and *no*, the mouth is opened after the *m* or *n* is pronounced, in order to give utterance to the next letter. These are two distinct acts, but the one succeeds the other so quickly, that they appear to be a single act. The nasal sound *ng* is the one which we employ in humming. Hence, the mouth is kept closed and the sound issues from the orifices of the nostrils.

392. A reverberation of sound in the back part of the mouth and the cavities of the nose constitutes a distinguishing peculiarity of many of the consonants. Thus, in pronouncing *b* and *p*, the lips are placed precisely in the same manner, and the

only difference between them is that *b* has the reverberation spoken of, but *p* has not. If you pronounce these two letters in the syllables *ap* and *ab*, for example, while you press on the nostrils with your fingers, you can feel the vibration occasioned by this reverberation in pronouncing *b*, but there is obviously none in pronouncing *p*. This reverberation is heard in the following alphabetical elements, B, D, G, V, Z (the sound of *s* in the word *as*), Y, W, Th (as in *thou*), Zh (the sound of *z* in *azure*), Ng, L, M, N, R. Those which have not this reverberation are P, T, K, F, S (as heard in *sun*), H, Wh (as heard in *which*), Th (as heard in *thing*), Sh (the sound of *s* in *sure*). That you may contrast these two sets of alphabetical elements individually, I place them here in two rows. B is like P, except that it has a reverberation, and so on through.

B, D, G, V, Z, Y, W, Th, Zh, Ng, L, M, N, R.
P, T, K, F, S, H, Wh, Th, Sh.

393. In what is commonly called speaking through the nose the reverberation mentioned above is disagreeably strong. The popular idea of it is incorrect, for this fault occurs in those who have some obstruction to the free passage of the air through the nose. This obstruction acts like the pressing of the nostrils with the fingers, confining more or less the body of air contained in the nasal passages. It is the vibration of this air thus partially confined in tortuous passages that produces the nasal twang. Any thing therefore which prevents the free outlet of the air from the nose will occasion it. Pressing the fingers on the nostrils while speaking, as already hinted, will produce it. A common example of it we have in what is called a cold in the head. The snuff-taker has this twang, because by such constant stimulation of the lining membrane it becomes thickened. Those who have this fault of "speaking through the nose," do not like others breathe ordinarily through the nose alone, but you see them sitting with their mouth constantly open, showing that there is so much obstruction in the nasal passages that they are not able to transmit sufficient air to the lungs.

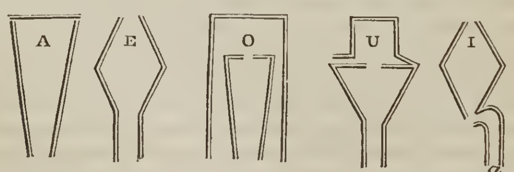
394. I have thus far spoken of articulation as employed in ordinary speech, that is with a vocal sound. But when no sound is produced by the ligaments of the larynx, as is the case in whispering, the noise produced by the passage of the air through the cavities of the vocal apparatus can be so articulated, as to be heard distinctly at a considerable distance. Persons, therefore, who have entirely lost the voice can converse. In

whispering the vocal ligaments are relaxed as they are when we simply breathe. But the sound of whispering has its high and low notes like the vocal sound. The variation of note is caused by variation of the size of the column of air contained in the vocal tube. This is effected chiefly by the tongue. In the high notes of whispering the tongue is nearer the roof of the mouth than in the low notes. The distinction between many of the letters as to reverberation noticed in § 392 holds in whispering as it does in ordinary vocal speech.

395. You can observe the mechanism of the parts that is necessary for any one of the alphabetic elements, by pronouncing some syllable which it ends, prolonging the sound of the letter in question. And in doing this you will readily see the incorrectness of the common definition of consonants, viz., that they are letters which cannot be sounded without the aid of a vowel. Take, for instance, the lettter *m* in the syllable *am*. After getting an idea of the mechanism necessary for it by sounding it with *a*, you can readily sound it alone. It is proper to remark here, that in observing the distinctions between the alphabetical elements, you must bear in mind that the names which are given to the letters in the alphabet do not represent their sounds. For example, H (aitch) and W (double-u) are nothing like the sound of these letters in *have* and *wave*.

396. Various attempts have been made to imitate the articulation of sounds by mechanism, but with very limited success. In 1779 a prize was offered by the Academy of Science at St. Petersburg, for the best dissertation on the theory of vowel sounds, and it was awarded to G. R. Kratzanstein, an account of whose experiments was published in the Transactions of the Academy. He found that the sound of the four vowels, A, E, O and U, might be produced by blowing through a reed into tubes, the forms of which are represented in Figures 142, 143, 144 and 145, and that the sound of I, as pronounced by the

FIG. 142. FIG. 143. FIG. 144. FIG. 145. FIG. 146.



Freneh and other European nations ean be prodneed by blowing into the tube, Fig. 146, by blowing at *a* without using the reed. M. Kempelen, of Vienna, the inventor of Maelzel's automaton ehess-player, carried the imitation of the human voice still farther. He produced an instrument capable of uttering eertain words and short phrases in Latin and Freneh. But it is not known exaetly how he accomplished this, as he kept the matter secret. A gentleman of Cambridge, England, investigated this subject, and among other things found that by blowing through a reed into a conical cavity, the vowel sounds could be produced by altering the size of the aperture for the passage of the air from the cavity, by means of a sliding board. I have alluded to these attempts to imitate the voice, to show by eontrast the wonderful completeness and perfection of the vocal apparatus. Kempelen's instrument, a box three feet long, could produee only a few words, but the instrument of the voice, although it occupies so little room in the body, can utter all words in all languages.

397. We have now examined the whole of the vocal apparatus. You will observe that I have spoken of it as having two parts, the larynx, which is the reed of the instrument, and the vocal tube, which you have seen is quite complicated, for the purposes of articulation. Every action in both parts of the instrument is produced by muscles. You have seen that the action of museles is requisite to eause any, even the slightest, variation of note. So it is with the articulating apparatus, as it may be ealled. Every alphabetical element, (and in our language Rush makes 35 in the whole,) requires a partieular adjustment of the articulating apparatus. This adjustment is effected by muscles that move the tongue, lips, palate, &c. As these muscles then perform sueh varied movements, to produce this variety of note and artieulation, it is no wonder that they require such long and diligent training. The child begins this long course of edueation the moment he utters an artieulate sound. Observe him as he pronounees the syllable *pa* or *ma*, the first which ehildren generally learn. He looks at his mother's lips, and imitátes the motion as well as he ean. Cheered by his success, and by her approving smile, he is eonstantly repeating these first lessons in pronunciation to every one that eomes near him. Being as yet without skill in the use of these organs, he gives much more foree than is necessary to the mechanical motions of artieulation. For example, in pronouneing the word *pa*, he closes his lips strongly, and not slightly as we do, and

when he opens it for the utterance of the word he does it with an explosive force, at the same time quickly bowing his head. The energy of his whole frame seems to be concentrated upon the effort. Day after day he strives to add to his stock of words, but his progress is slow; and as a sort of compensation for the leanness of his stock he repeats those which he has learned, and so of his own accord he says papa and mamma instead of using the words of a single syllable. In this education of the organs of the voice the ear is the principal instructor, but the eye, as you see, is also of great assistance. The little pupil, on hearing a sound which he wishes to utter himself, tries to imitate the motion which he sees is used in producing it, and he continues to try till his ear assures him that he has actually mastered the sound. Soon he is able to utter two different articulate sounds in succession; and he goes on learning year after year, till at length he can command all the sounds of his native tongue. And I may remark that it is in childhood and youth alone, that we can learn accurately and thoroughly the pronunciation of a language that is at all difficult in this respect. Hence a foreigner, however long he may live in a country, to which he goes in adult life, cannot wholly conceal his native accent. And we know how much such sounds as that of *th* trouble the German and the Frenchman, unless they begin to learn the English language early in life.

398. If we observe different persons while speaking or singing, we shall see that some manage the vocal apparatus, or play on the vocal instrument, as we may express it, with more skill than others. Listen to two persons in conversation, the one modulating and articulating his voice with a graceful melody, the other having an utterance harsh and awkward; and the contrast is as great as that between two instruments, one of which is well and the other badly played. In some you can almost imagine that you hear the creaking of the machinery; while in others you do not once think of the mechanism of the voice, but your ear feasts upon its richly modulated and gracefully articulated sounds. It is as true of the muscles of the vocal apparatus as of those of any other part of the body, that skill in the management of them can be very much increased by exercise. The rope-dancer, by training his muscles, gives them a wonderful precision of action. The same thing can be done with the muscles that regulate the modulation and articulation of the voice. And in the most noted singers the little muscles which move the vocal ligaments and those which adjust the

parts of the vocal tube, must have a precision of action incomparably more accurate and delicate than the large muscles in the limbs of the rope-dancer. If we compare the limited and bungling operations of the vocal apparatus in a little child just beginning to talk, with its infinitely varied but precise movements in a voluble speaker, or a skillful singer, we shall have some conception of the delicacy of motion, of which the muscles of this apparatus become capable by long continued exerçise.

399. There is a defective action of the muscles of the vocal apparatus, called stammering or stuttering, which I will just notice. It is an irregular spasmodic action of these muscles, very much like that which we see in the muscles of other parts of the body in the disease called St. Vitus' dance. It is very much influenced by habit, and mental agitation aggravates it. Shakspeare gives the following accurate description of it. "I would thou wouldst stammer, that thou mightest pour out of thy mouth, as wine comes out of a narrow mouthed bottle, either too much at once, or none at all." It is a singular and instructive fact, that many who stutter in ordinary conversation can read and sing as well as others. Dr. Good remarks that one of the worst stammerers he ever knew was one of the best readers of Paradise Lost that he ever heard. Such facts suggest some valuable principles in the treatment of this difficulty, which can be more easily overcome than is commonly supposed.

400. Not only is the ear the educator of the muscles of the voice, but the dependence upon the ear is entire. The deaf and dumb therefore are in almost every case dumb because they are deaf. Their vocal organs are in a good condition, and the muscles are all there with their nervous connections. But the machinery does not work, for there is no guiding power to direct it. That this is the true view, is proved by those cases in which hearing has been restored, for such restoration is followed by that of the power of speech. Magendie relates an interesting case of this kind. It was the case of a young man deaf and dumb from birth, who had his hearing restored by M. Itard. He first heard the sound of the neighboring bells, which not only caused very lively emotions, but even headache and dizziness. The next day he heard the sound of the small bell in the room, and shortly after he could hear the voice of persons speaking. His delight was then extreme, and he was so absorbed in his new enjoyment that, says Professor Percy, "his eyes seemed to search the words even on our lips." His voice was soon developed. The muscles of the vocal organs, so long

inactive, began to wake up under the tuition of their instructor, the ear. Only vague sounds were formed at first, and, although after a while he could pronounce some words, he did it awkwardly as children do when they are beginning to talk. He learned to talk very slowly. It would have been very interesting to have watched this case in its progress, but this was prevented by a disease which proved fatal.

401. Few cases occur like that which is related above, but there are many cases in which the dependence of speech upon hearing is proved in another way. I refer to those cases in which the loss of the power of speech is obviously the consequence of the loss of the hearing. This is the case with children that become entirely deaf after they have made some progress in learning to talk. They cease to talk, and very soon forget the motions which they had learned to make in articulation. Sometimes some of these motions are remembered, and the individual can pronounce some words. But he does it very awkwardly, and the consciousness of this makes him very averse to trying it. A friend mentioned to me the case of a man who became deaf just after he had learned the alphabet. He remembered the mechanical effort necessary to produce each letter, but he had no control over the loudness or note of the voice, so that some of the letters he sounded very high, others low, some very loud, and others soft, making of course some laughable contrasts. It is undoubtedly possible to teach deaf and dumb persons to talk to some extent, if we begin early enough; but the power of speech, after the most persevering training, must be awkwardly mechanical, and exceedingly limited. Accordingly all such efforts have been very soon given up.

402. The question has probably arisen in your minds as to what the difference is between the voice of speech and the voice of song. The common notions on this subject were very indefinite until recently. But Dr. Rush, in his admirable work on the voice, has developed the true principles in regard to it. He has shown that we use the same notes in speech and song, and that the difference lies in the mode of using them. I will endeavor to place before you the most prominent and material points in his view of this subject.

403. If you pronounce the sound *a* as heard in day, you will observe that it ends in another sound, that of *e*. The voice in pronouncing it rises through the interval of a tone, the sound at the same time gradually diminishing. So of other letters. Thus, *a* as sounded in *awe*, ends or vanishes in *e* as heard in *err; o*

as heard in *old* vanishes in *oo* as heard in *ooze;* and *ou* as heard in *our* vanishes also in *oo*. The vanishing sounds are of course rather obscure and feeble. The first sound he calls the "radical movement of the voice," and the subsequent diminishing sound its "vanishing movement." The rise of the voice during the vanishing movement is not always through the interval of a tone, but it may be only a semitone, or it may be even through the interval of an octave. In singing the movement is very different. We pass "quickly and faintly through the radical movement to dwell with greater time and fullness on a note or level line of sound at the extreme place of the vanish." Both in song and speech there is also a downward as well as an upward movement on the scale. The gliding of the voice on the scale, and its gradual vanish cannot be imitated on instruments. They may be imitated to some extent however on the violin if the finger moves along the string while the bow is drawn. The difference between the voice of speech and song is thus represented by Dr. Rush:

At 1 is represented the vanish on the interval of a tone; at 2 on that of a third; at 3 on that of a fifth, and at 4 on that of an octave.

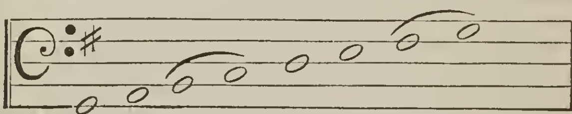
404. I will notice very briefly the use of the vanishing movement in speech. In simple narrative the vanish never rises above the interval of a tone, as at 1. Whenever it rises higher it is either for emphasis or interrogation. The vanish on the interval of a fifth, as at 3, is the most common mode of interrogation. That of the octave, 4, is used when the question is asked with great vehemence, or is accompanied with sneering, mirth, contempt, or raillery. Thus when the Jew in the Merchant of Venice asks,

> Hath a *dog* money? Is it possible
> A *cur* can lend ten thousand ducats?

there is a rise through the interval of an octave on the words *cur* and *dog*. You observe that the rise is on the words which are emphasized. Thus we can make four entirely different

sentences of the question, do you ride to town to day? according as we make the rise on *you*, or *ride*, or *town*, or *day*. By the use of this rising vanish we can make a question of the most positive assertion, even of the blunt negative, no.

405. The vanish on the interval of a semitone gives the voice a plaintive character, and it is therefore used for the expression of love, grief, supplication, &c. It is sometimes used so much as to give a general character of plaintiveness to one's whole conversation. As a very clear and striking illustration of the power of the semitone we will take the cry of fire. Divide the word into two syllables, fi-yer, and ascend the scale thus:



Fi–yer. Fi–yer Fi–yer. Fi–yer.

The two places of the semitones, indicated by the braces, will give the cry of fire as we commonly hear it. Sometimes we hear it cried in sport upon one note, and the sound is discordant and ludicrous. So also, the two words, "*O dear*," sound like a mere mockery of grief, if uttered on one note, or any other interval than the semitone.

406. Every one learns to talk, but there are many who do not learn to sing. Now as the same notes are used in the two cases, what is the reason of the difference? The reason is not in an absolute inability to appreciate the variations of note in sound, for these are practically appreciated in the use of the vanishing rise in conversation. There are two reasons for the difference. One is this. As the transitions of the voice from one part of the scale to another are much more varied in song than in speech, and are made by leaps instead of slides, song requires greater skill than speech does in the action of the muscles. Another reason is, that speech is a *necessity*, and song is not. We learn to speak therefore as a matter of course, but singing is a mere accomplishment. If it were learned as universally as speaking is, there would be nearly as much good singing as good speaking. We can realize the truth of this assertion, when we observe the results of very early training in singing. And we should realize it still more if singing were universally considered, as it should be, as an essential part of

the education of children. And I may remark in this connection, that all have some measure of musical talent, though in some it is exceedingly small in amount. The difference in this respect in different persons is the same as the difference in regard to any other talent, as that of drawing for example. Skill is acquired in the same way in both cases, and its degree depends to the same extent, and in the same manner upon natural endowment.

407. Some persons possess extraordinary powers in the use of the vocal organs. I refer to ventriloquism. This is a purely imitative art, and is not to be attributed to any peculiar formation of the parts in the individual who possesses the power. The ventriloquist must have the faculty of appreciating with great accuracy the almost infinite variety of tones, articulations, and inflections of the voice, and must be able to imitate them with but little motion of those parts of the articulating apparatus which appear in view. He at the same time makes skillful use of those circumstances, which will favor the false impressions in the minds of his audience, in relation to the locality of the source of the sounds. This is the simple explanation of this wonderful power.

CHAPTER XV.

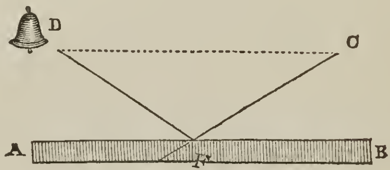
THE EAR.

In the last chapter I treated of the production of sound by the vocal apparatus. In this chapter I propose to show you how the impression of sound is transmitted to the brain, in order to produce the sensation of hearing.

408. That you may the better understand the arrangement of the apparatus of hearing, I will first notice some of the principles that govern the transmission of sonorous vibrations. Sound may be produced by the vibration of any substance; though some are better fitted to produce it than others, and are therefore called sonorous bodies. When the vibrations which cause sound are equal, a *musical sound* results; but if they are

unequal, we have a discordant sound, or what we ordinarily call a *noise*. Sound is transmitted from the point where it originates, in all directions. And its vibrations gradually lessen, just as the ripples lessen which are produced by dropping a stone into the water. The vibrations of sound are reflected by objects against which they strike. For this reason the voice can be heard at a much greater distance if it be transmitted along a wall than when it is uttered in an open space. This may be illustrated on Fig. 147. Let A B represent a wall, and

FIG. 147.



C the position of the ear. If the bell at D be rung, besides the vibrations which come to the ear at C in the direct line C D, a vibration striking the wall at F will come to the ear in the line F C, and the same can be said of other points along the wall. An accumulation of vibrations, therefore, comes to the ear at C, which therefore receives a louder sound from the bell than it would if the bell were rung in a perfectly open space. For the same reason a speaker can be heard much more easily within walls than he can be in the open air. The sound is reflected, and, therefore, in some measure concentrated by the walls. In speaking tubes this reflection and concentration are carried to a still greater extent. Sound can in this way be heard at a great distance from its source. M. Biot found that when he spoke in a whisper at one end of a tube, over three thousand feet in length, he was distinctly heard at the other end; so entirely do the walls of the tube prevent the diffusion of the vibration in the air around. Speaking tubes are therefore used to a great extent in large manufactories, where directions need to be given continually to workmen in different parts of the establishment. The flexible tube, now so commonly made use of by deaf persons, furnishes another illustration. The vibrations of the voice received by the trumpet-shaped end are transmitted through the tube to the ear.

409. Sound may be transmitted through any substance, whether it be solid, liquid, or gaseous. It cannot be transmitted through a vacuum, for there is nothing there to vibrate. Sound differs in this respect from light, which passes as readily through a vacuum as it does through any transparent substance. The fact that sound cannot be transmitted through a vacuum is often illustrated by an experiment with the air-pump. If a bell be put under the receiver, and be set to ringing, as the air is exhausted by the pump, the sound becomes more and more faint, and at length it is not heard at all. For the same reason, a pistol fired on the summit of a mountain, gives nothing like so loud a report as when it is fired in the valley below. The more solid the medium is for the transmission of sound, the more readily is it transmitted. The scratching of a pin at the end of a long log may be heard by the ear applied to the other end, although it cannot be heard through the air, at even the distance of a few feet. Savages are in the habit of putting the ear to the ground to hear the step of their enemies when they apprehend their approach. A deaf gentleman, resting the bowl of his pipe on his daughter's piano-forte as he smoked, found that he could hear the music with great distinctness; and many deaf persons can hear conversation, by holding a stick between their teeth, while the other end rests against the teeth of the person speaking. A knowledge of the ready transmission of sound through solids suggested the examination of the chest in disease by the ear. If the ear be applied to the chest, the various sounds produced by the air, as it passes through the bronchial tubes into the air cells, can be heard through the solid walls of the chest, and thus the state of the lungs can be discovered. Water is a much better conductor of sonorous vibration than air, though it is not as good an one as a solid substance. The force of the vibration is lessened more gradually in water than in air, and its rate of progress in water is, according to Chladni, 4,900 feet in a second, or between four and five times as great as in air.

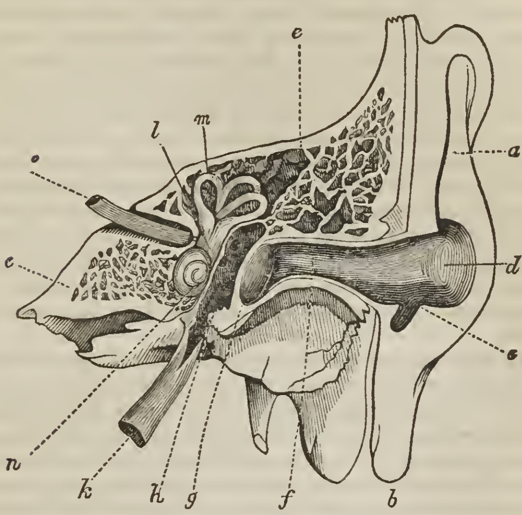
410. Sonorous vibration does not pass readily from one medium to another. Thus, although the scratch on the log is heard so easily by the ear at the other end, if the ear be removed a little from the log, it does not hear the sound, because the vibration is so much lessened in passing from the solid wood to the air. It is clear that the more unlike the two substances are, when sound passes from one to the other, the more will the vibration be lessened; for the more unlike they

are, the less easily will the one take the vibration from the other. For this reason, a sonorous vibration, produced in a solid body, may be transmitted to water with much less loss of intensity or force, than occurs when it is transmitted to air. And it may be remarked in this connection, that when vibrations are transmitted to a fluid, from air or from a solid, the intervention of a membrane is of essential service, for it presents a firm surface upon which the vibrations can be received.

411. The principles which I have thus noticed will be seen to apply to the arrangement of the apparatus of hearing, as we proceed in the examination of it. It has various parts for the different portions of the process which we call hearing. I will premise a mere general description of this process, before entering upon the examination of the apparatus in detail. The vibrations of sound, passing into the ear by a tube, strike at the bottom of that tube upon a drum. The air can go no farther, for this drum is perfectly air-tight. It communicates its vibrations, however, to the drum, which transmits them to a chain of four little bones, the last of which transmits them to another drum, covering an opening into various winding passages in solid bone. In these passages is contained a limpid fluid, which is put in motion by the vibrations of the drum last mentioned. So much for the mere mechanical part of the process. In the winding passages are spread out the minute fibres of the nerve of hearing. The vibrations of the liquid in these halls of audience, as we may call them, make an impression upon these nerves, which is communicated to the brain through the trunk of the nerve, and this completes the whole process necessary to the production of the sensation of hearing.

412. The parts of the apparatus of hearing may be seen in Fig. 148. The internal portions are made rather larger than natural, in order that the arrangement may be more clear. At *a b c* is the external ear; at *d* is the entrance to the tube of the ear *f; g* is the drum of the ear at the end of this tube, called the membrane of the *tympanum; h* is the cavity of the tympanum, the chain of bones which it contains being left out, so that the plan of the apparatus may be more clear to you; *k* is the Eustachian tube, which makes a communication between the back of the throat and the cavity of the tympanum; *n* is a part of the winding passages, shaped like a snail's shell, and is therefore called the *cochlea;* at *m* are three other winding passages, called, from their form, *semi-circular canals;* and at *l* is the *vestibule*, or common hall of entrance to all these

FIG. 148.



VERTICAL SECTION OF THE ORGAN OF HEARING.

winding passages. In the cavity of the tympanum, on the side opposite to the drum of the ear, you see two holes. These open into the windiug passages, the larger one into their vestibule or entrance hall. Both of these holes are covered by a membrane, and to the membrane of the larger one is attached the last of the chain of bones. At *o* is the trunk of the nerve of hearing, and at *e e* is the bone that incloses these parts, which is so hard that it is called the *petrous*, or rock-like bone.

Having given you this general view of the apparatus, I shall now speak of each part more particularly.

413. The object of the external ear is to collect the waves of sound, and direct them into the tube of the ear. There have been many speculations in regard to the use of the prominences and ridges of the external ear, but they are fanciful and groundless; and its surface is thus diversified, probably for the sake of making this organ a comely one. If the object were to give it the best shape and arrangement for collecting the vibrations of sound, it would have had a different shape altogether, and

would have been arranged with muscles which could turn it in different directions, as is the case with many animals. The shape of the external ear is much better in many animals than it is in man, if we consider its object to be merely the collection of the waves of sound. The endowment is in this case, as well as in every other, according to the necessities of the case. The bat is guided so much in its movements by the sense of hearing, that it has of necessity very large ears, and they are so shaped as to collect, in the best possible manner, the vibrations of the air. With proportionably large, and similarly shaped ears, man could hear much better than he now does, but he has no need of such ugly appendages. In regard to the motions of the ears in animals, it is worthy of remark, that animals of prey can turn their ears forward with the most facility, while timorous animals turn their ears backward to keep warned of danger.

414. The tube of the ear is about an inch long in the adult. It is formed of cartilage like the external ear, and ends at the drum. At its entrance are hairs which afford some protection against intruders. But the chief protection is the bitter wax, which is secreted by little glands, situated in the skin of the tube. The odor from this secretion so effectually keeps out the insects from this open entrance, that it is quite a rare occurrence to have an insect get into the ear. And when one does get in, the wax envelopes him, and commonly soon destroys him.

415. The drum of the ear, which makes the closed end of the tube above described, as seen at *g*, Fig. 148, is very thin and transparent. On the other side of it is the cavity of the tympanum *h*. In this cavity are the four bones. These are represented in Fig. 149, enlarged so that you can see their shape distinctly. They are named from their shapes. They are the *malleus* or hammer *m;* the *incus* or anvil *i;* the *os orbiculare*, or round bone *o*, the smallest bone in the body; and the *stapes* or stirrup-bones. The long handle of the hammer *h* is fastened to the middle of the drum of the ear. The little round bone is fixed between the slender end of the anvil, and the top of the stirrup-bones. In Fig. 150 you have a representation of these bones, together with the drum of the ear. While the end of

FIG. 149.

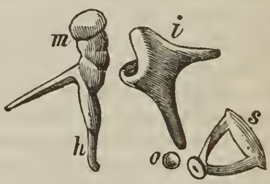


FIG. 150.

DRUM OF THE EAR with the bones.

the handle of the hammer is fastened to the middle of the drum, the base of the stirrup is fastened to another drum, covering the hole or window, opening into the vestibule of the winding passages. There are three very delicate muscles which move these bones. One of them relaxes the drum of the ear, and another makes it more tense; and thus the drum is put into the right states of tension, to accommodate it to the various kinds of vibration that come to it. This is a matter of some importance, for it is plain that while a relaxed drum can vibrate properly to grave sounds that enter the ear, it must be tense, in order to respond properly to the vibrations of the air in the higher notes.

416. The cavity of the tympanum (*h* Fig. 148) in which the little bones are, and which is beyond the drum, communicates with the mouth by the Eustachian tube *g*. If you shut your mouth, and close the nostrils with the fingers, and then perform the action of blowing, you will feel the air enter the Eustachian tubes, and fill the cavity of the tympanum. The chief object of this communication is to have air on the inside as well as the outside of the drum, so that it may vibrate freely. The cavity of the tympanum might indeed have been a closed cavity, containing air. But it would then have been very much like a common drum, with the hole in its side closed. This would very much impair the vibration.

417. We now come to another part of the apparatus of hearing—the winding passages. These are inclosed, as I have already stated, in the most solid bone in the body. They are called together, very appropriately, the *labyrinth*, sometimes the *internal ear*. This is really the essential part of the apparatus. Here are the true halls of audience, where the nerve is posted, which receives the messages from without, and transmits them to the brain. The drum of the ear and the chain of little bones may be destroyed, and yet, if these winding passages remain entire, with the membranes over the two windows that open into them, the hearing will not be lost; though it will be less perfect than it is when the whole of the apparatus is there, and in good order. Sir Astley Cooper relates the case of a gentleman, who lost the drums of both ears by disease. By shutting his mouth, he could blow the air out through his ears, with such force as to make a whistling noise, and to move

the hair that hung from his temples. Yet he was not only able to hear with ease all common conversation, but he had a nice appreciation of musical sounds. Sir Astley says that "he played well on the flute, and had frequently borne a part in a concert; and he sung with much taste, and perfectly in tune."

418. The labyrinth is represented much magnified in Fig. 151. The middle part of it, *v*, is the *vestibule*. From this go out the *semi-circular canals*, *x*, *y*, *z*, on the upper side, and on the lower the winding passages of the cochlea, *k*. At *o* you see the opening called the *fenestra ovalis*, or oval window. This is covered by a membrane, on which presses the base of the stirrup-bone. You see another opening *r*, which is called the *fenestra rotunda*, or round window. This is covered with a membrane. Both of these openings you see in Fig. 148, in the cavity of the tympanum, opposite to the drum of the ear. In these winding passages is a watery fluid, the vibrations of which, acting upon the branches of the nerve distributed there, cause the sensation of hearing. Of course, if either of the membranes covering the openings into these passages be destroyed or broken, the fluid will run out from the ear, and there can be no more hearing, although the rest of the apparatus is perfect. The drum will continue to vibrate as sounds strike upon it, the little chain of bones will repeat the vibration, but it will stop at the end of the chain, the stirrup-like bone. So too, although the membranes may be entire, and the whole apparatus may be perfect as a piece of mechanism, so that the succession of vibrations from the air without through the drum and the chain of bones, to the fluid of the labyrinth, is uninterrupted, if the nerve of hearing be paralyzed, so that it cannot be impressed with the vibration of the fluid that bathes its branches, there can be no hearing. Partial deafness is undoubtedly often owing to a thickening of the fluid in these passages, or to a partial failure of the nerve distributed in them.

FIG. 151.

419. It will be proper to say a word here in relation to the choice of a fluid, instead of a solid or an aeriform substance, as the medium through which the impression of the vibration of sound is communicated to the nerve. It is better than a solid would be, so far as we can see, because no arrangement of a vibrating solid with the minute fibres of the branches of the nerve could be effectual, and at the same time so little liable to derangement, as the arrangement of nervous fibres immersed in a liquid, and the whole inclosed in solid walls of bone. It is better than air would be, for at least two reasons. 1st. The vibrations of sound, as stated in § 409, are communicated with much more ease and rapidity through water than through air. This we see to be a consideration of some importance, when we look at the complicated and winding passages that contain the fluid. 2d. There is not as much loss in the force of the vibration in the transmission from the solid stirrup-bone through the membrane to the fluid, as there would be if the transmission were to air.

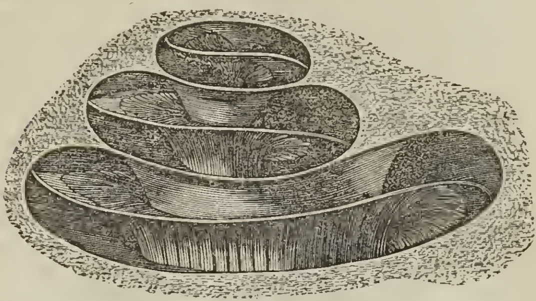
420. The whole arrangement in regard to material we can see to be admirable, if examined in relation to the known principles of the transmission of sound. We can see the object of the chain of bones. If these were left out of the arrangement we could hear, but not so well as we do now. For it has been ascertained by experiment, that the transmission is much more perfect when the vibration passes, as in the case of the ear, through a tense membrane, then through a chain of solid substances, and from them through a second membrane to the fluid, than it is when the chain of solid bodies is omitted, and air is made to take their place. And when the vibration has arrived at the fluid in the labyrinth, there is a contrivance there for increasing its intensity. There are two little chalky concretions suspended in this fluid by nervous fibres. These are found in all mammalia, and in fishes they are quite large and hard. This being the case, it was inferred that these bodies have some important influence upon the transmission; and it has been found by experiment that hard bodies thus situated in a fluid increase the sonorous vibrations in their neighborhood.

421. You will remember that there are two openings into the labyrinth, from the cavity of the tympanum. Both are covered by membranes, one of which is pressed upon by the stirrup-bone, while the other is free. It was formerly supposed that the second opening was absolutely essential to the vibration of the fluid in the labyrinth. For, as fluids are incom-

pressible, it was inferred that, as the stirrup-bone communicated its vibration to the membrane of the *fenestra ovalis*, the fluid in the labyrinth would not vibrate, unless there was another opening some where, the membrane of which would yield to pressure. This, however, has been ascertained to be not strictly true. It has been proved by experiment that a sonorous vibration can be transmitted through a confined fluid. Indeed there are some animals in which there is only one opening into the labyrinth. But, although this second opening is not essential to the vibration of the liquid, it undoubtedly makes that vibration more perfect. Although the second opening is so near the first, as seen in the cavity of the tympanum, (Fig. 148) yet in relation to the arrangement of the winding passages of the labyrinth, as you will soon see, it is really quite at the other end of it. The vibration then may be considered as communicated through a long tube, which has a membrane at both ends. And it is obvious that a vibration communicated to the membrane at one end, will more readily move the fluid throughout all the tube, from the yielding of the membrane at the other end. This will be more obvious, as I describe more particularly the arrangement of the passages in the labyrinth, which I will now do.

422. To recur to Fig. 151, the vestibule *v*, into which the *fenestra ovalis o* opens, is, as before stated, a sort of common entrance hall to all the passages of the labyrinth. I have spoken of the semi-circular canals *x*, *y*, and *z*, that lead out from this. These are simple canals. But the passages of the *cochlea*, *k*, are very complicated, and it is this fact that has given the name of labyrinth to the whole of the internal ear. The vestibule opens into the cochlea at its base. Now, the cochlea is so divided, that the passage into which the vestibule opens, runs around the pillar in the middle of it to its top, making just two turns and a half. It there opens into another passage, which makes two turns and a half back to the base of the cochlea. This passage does not end in the vestibule where the other began, but it ends in the round hole *r*, which opens into the cavity of the tympanum. This disposition of the parts of the cochlea may be seen in Fig. 152, which represents it as opened to show the arrangement of the walls of the two winding galleries. The pillar in the middle, around which these dividing walls are fastened, expands in the top into what is called a cupola, where the two spiral galleries communicate together. With this description, you can understand in what

FIG. 152.

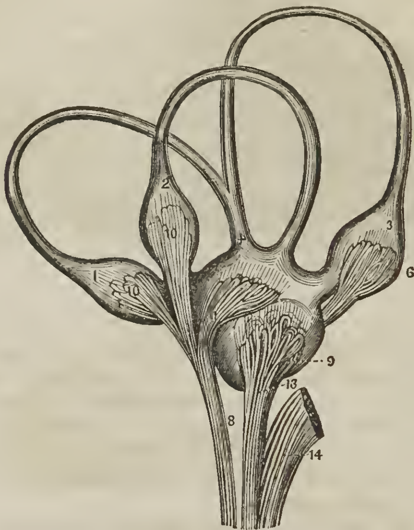


THE COCHLEA OPENED.

directions the vibration is transmitted, when it is received from the stirrup-bone, at the door of the labyrinth, by the membrane which covers it. It travels one way up the fluid in the three semi-circular canals. It travels another way through one spiral gallery in the cochlea to the cupola, and then down the other spiral gallery, reaching at length the membrane of the *fenestra rotunda*, or round window.

423. I will now describe to you the arrangement of the branches of the nerve of hearing in these passages. The arrangement is different in the vestibule and the semi-circular canals from what it is in the cochlea. In *all* the cavities of the labyrinth, there is a thin, delicate lining of membrane, which secretes a watery fluid. In the vestibule and semi-circular canals, there is a second membrane. This is separate from the first membrane, and lies loose in the cavities. It makes a close sac, and as it extends from the vestibule into the semi-circular canals, it is very irregular in its form. This sac contains a fluid, and the fluid secreted from the membrane which lines the bone bathes the outside of the sac. Now, it is on the delicate membrane which forms this sac, that the fibres of the nerve are distributed, so that they may receive the impression of the vibration of the fluid. In Fig. 153, is a representation of this sac, with the distribution of the nerve. At 1, 2, and 3, you see the parts of this sac which line the semi-circular canals. At 4 is a junction of two of these canals, for what purpose we know not. At 6, 9, 10, and 11, are seen the terminations of branches of the nerve. At 8 and 13 are two of these branches,

FIG. 153.



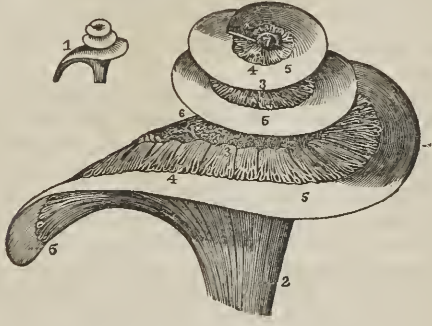
and at 14 is the branch of the nerve which goes to be distributed in the cochlea. In Fig. 154 is represented one of the parts

FIG. 154.

where the nerve terminates, as at 10 in Fig. 153, much more highly magnified. You see the loop-like termination of the nervous fibrils. You can readily see that every vibration of the fluid would make an impression upon these nervous fibrils thus distributed upon this delicate membrane, which has the fluid upon both sides of it.

424. The distribution of the nerve is after a different manner in the cochlea. Here there is no loose membrane, with the nerve distributed upon it, and the fluid each side of it, as in the vestibule and the semi-circular canals. But the nerve is distributed upon the division wall of the galleries in a very beautiful manner. This is represented in Fig. 155, in which 2

FIG. 155.



is the nerve, and 3, 3, 3, show its distribution. These fibrils lie in little channels in a lamina, or leaf of solid bone. But the bone extends only to 4, 4, and the remainder of the division wall is made of membrane, represented at 5, 5, 5. At 7 is the opening in the cupola, by which the two spiral galleries communicate. At 1 you have these parts of the natural size. We know not exactly how this mechanism works, but the probability is, that the nerve receives impressions from the vibrations of the fluid in two ways—directly from the fluid itself, and also from the vibration of the membrane to which the extremities of the nerve are attached, this membrane being shaken of course by the vibrating fluid.

425. Having thus described the parts of the organ of hearing, I will trace for you, with some particularity, the steps of

the process of hearing, as it must occur in the case of every sound that produces that sensation. The vibrating air enters the tube of the ear, and, reaching the drum, produces a vibration there. This vibration is communicated to the chain of bones, which, as Dr. Paley very aptly says, like a repeating line of frigates pass it on. It is transmitted from the last of this chain of bones, the stirrup-bone, to the membrane covering the *fenestra ovalis*, and from this to the fluid contained in all the passages of the labyrinth. The vibration goes through all the semi-circular canals in one direction, and in another up one gallery of the cochlea, and down the other. In all these cavities, are spread out in various ways, the filaments of the nerve which receive the impression of the vibration. This impression is transmitted from the extremities of the nerve, through its trunk, to the brain, where the mind receives it. All this together constitutes hearing; and all of it occurs in the case of any sound which we hear, however closely it may follow any other sound.

426. Most of our hearing is done precisely in the way described, but not all. We sometimes hear directly through the bone surrounding the labyrinth. If you place a watch between the teeth, you hear the ticking; and it gives a very different sound from what it does when held to the ear, because the sonorous vibration is transmitted directly through the solid bones of the skull from the teeth. In the same way was the sound transmitted in the case of the deaf old gentleman, (§ 409) who heard his daughter's music through the stem of his pipe, as he rested the bowl of it on the piano. The fact thus illustrated is often made use of by physicians, in detecting the nature of the difficulty in cases of deafness. Thus, if a watch held between the teeth communicate a very distinct and loud sound to the ear, we infer that the internal ear is in a good condition, and that the difficulty is in some of the other parts connected with it, the drum, or the cavity of the tympanum, or the Eustachian tube.

427. I have described the apparatus of hearing as we find it in man. But it varies in different animals, according to the circumstances in which they are placed, and their necessities. Animals that live in water of course have a different apparatus of hearing from those that live in air. In most fishes the semi-circular canals exist, but there is nothing like a cochlea. As sounds are transmitted so easily through water, (§ 410,) fishes have no need of so complicated and perfect an apparatus

as animals that live in air. They are fitted to hear in their own element, and probably the moment that a fish is taken out of the water he becomes quite deaf, because his hearing apparatus is so poorly fitted to receive and transmit vibrations from the air. But in many animals that live in air the ear differs from that of man in its arrangements. The cochlea in birds is nearly straight instead of being spiral. Such facts lead to the inference, that the peculiar arrangements in the hearing apparatus of man have regard, not merely to the medium in which he is placed, but to peculiar uses which are necessary in his case, as the determination of the direction of sound, the appreciation of its pitch and its character, the power of hearing very slight sounds, &c. The simplest form of apparatus found in animals, is a cavity excavated in bone, with a fluid shut in it by a membrane, and nervous filaments distributed so as to be impressed by the vibrations of the fluid. And this is all that is absolutely essential to hearing.

428. Many speculations have been broached in regard to the special offices of particular parts of the labyrinth. Thus, it has been supposed that the semi-circular canals have an agency in informing us of the direction of sounds; for it is observed that they are always arranged in the same relative angle to each other. It has been supposed also, that the cochlea gives us the idea of the note of sounds, because it is noticed that the development of this part in different animals is in proportion to the variety of note which they produce. These suppositions, though quite probable, require farther investigation in comparative anatomy to test their truth.

429. In the process that makes up the sensation of hearing, there is one part which we can in some measure understand, and to which we can apply the known principles which govern the transmission of sonorous vibrations. But there is another part, that which links the process to the immaterial mind, that we cannot understand. We can trace the vibration received from the air through the several parts to the fluid in the labyrinth, but here we come to a stand in our knowledge. The vibration stops here, and what is transmitted through the nerve to the mind we know not. We call it an impression; but this is only an indefinite word, implying simply that something is transmitted, without defining what it is. Neither do we know *how* the transmission is made. All that we do know is, that the nerve is essential to the completion of the sensation of hearing, and that it spreads out its minute fibrils or tubuli in the

halls of audience, in order to receive impressions from the vibrations that come there, and transmit them to the brain where the mind takes cognizance of them. Every part of the apparatus may be mechanically perfect, so that the vibrations may be transmitted to the fluid which bathes the nervous fibrils, but if the nerve be paralyzed, or if the communication between its extreme fibrils and the brain be in any way interrupted, the mind knows nothing of the vibration, and there is no hearing.

430. The eye has generally been spoken of as being more wonderful than any other organ in the body, in view alike of the delicacy, the beauty, and the complication of its structure. But the apparatus of hearing presents a combination of these qualities quite as wonderful. There is nothing more delicate, and beautiful, and complicated than the arrangement of the nervous fibrils in the winding labyrinthic passages of the halls of audience. And as we trace the steps of the process of hearing, from the drum of the ear where the sound strikes, to the gray substance of the brain where the mind receives the impression, and think of each sound as sending a vibration through membranes and a chain of bones to the fluid in which the nervous fibrils are immersed, and of these fibrils as catching from every vibration of the fluid a definite impression and transmitting it to the mind, we see a mingling of the purely mechanical with the spiritual, which greatly enhances our admiration of the mechanism. Though the apparatus is complicated, the mechanical result is a simple one—it is a mere trembling of a fluid inclosed in winding cavities of bone. But simple as the result is, it is made, through the beautiful nervous connections of the ear with the brain, one of the chief inlets of knowledge to the mind, coming to it from nature's multitudinous voices, and is a constant medium of communication for thought and feeling between man and man. Thus intimately in the human body are the simplest mechanical results connected with the complicated and diversified operations of the mind. In the process of hearing the drum of the ear is to be considered one end of the apparatus, and the gray portion of the brain the other. The drum simply vibrates; and instantaneously the mind receives a distinct impression from the vesicles of the gray matter. And thus is the communication established between the immaterial mind, and the vibrations of the material substances with which it is surrounded.

CHAPTER XVI.

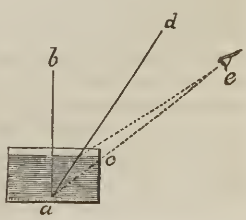
THE EYE.

431. The sensation of sight is the result of a compound process, which may be divided into two distinct parts, as I remarked in relation to the sensation of hearing, in § 429. The one part is purely mechanical, and the apparatus for it is constructed according to the common principles, which we find illustrated in optical instruments. The object of its arrangements is to form distinct images of objects in the back part of the eye. The other part of the process is executed by the nerve of vision, called the optic nerve. This nerve, expanded upon the membrane where the images are formed, transmits impressions from these images to the brain, just as the nerve of hearing transmits to the brain the impressions which come from the vibration of the fluid of the labyrinth.

Before proceeding to an examination of the eye as an optical instrument, I will call your attention to certain principles, which we shall find illustrated more beautifully and perfectly in the eye than in any optical instrument which man has ever constructed.

432. The rays of light coming from any luminous point go in straight lines in all directions, just as the vibrations of sound do, and, like them, become less intense the farther they are diffused. But they move in straight lines only so long as they remain in the same medium. When they pass from one medium into another they are bent out of their straight course, or *refracted*, as it is termed, unless they pass from one to the other in lines perpendicular to the surface of the medium which they enter. This may be illustrated by the following experiment. Place a coin, *a*, in the bottom of a basin, as represented in Fig. 156, and then withdraw from it so far that the coin may be hidden from your eye by the edge of the basin, as represented in the figure. Keeping your eye fixed in that position, pour some

FIG. 156.



water into the basin up to the level, *c*. The coin will again become visible to your eye. The reason is, that the rays of light, as they come from the water into the *rarer* medium, the air, are refracted or bent downwards, that is *from* the perpendicular. The effect of this may be seen in the figure. A ray of light, coming from the coin in the direction *a*, *d*, does not pass to *d*, but is bent downward, and so passes to the eye at *e*. And so of other rays coming from the object. The coin, therefore, is seen by the eye at *e*, but it is not seen in its true direction from the eye which is in the line *e*, *c*, *a*. The only point in which the eye can see the coin in its true position is when the eye is at *b*, in a perpendicular line directly over it. A ray that passes from one medium to another in a line perpendicular to the surface of the medium into which it passes is not bent out of its course. All other rays are, and the more so the farther they are from the perpendicular.

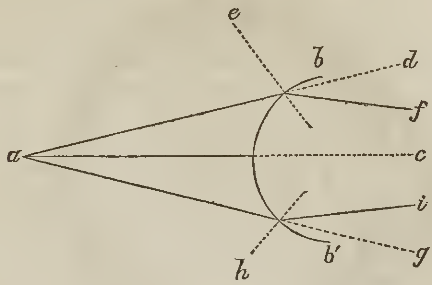
433. While rays that pass from a dense medium into a rarer, as from water into air, are bent *from* the perpendicular, those on the other hand, which pass from a rarer medium into a denser, as from air into water, are bent *towards* the perpendicular. Thus if in Fig. 156 *a* be the position of the eye of a fish, and where the eye is, at *e*, there be an insect, the fish can see it, because the ray that strikes the surface of the water, *c*, is refracted or bent towards the perpendicular line, *b*, *a*. And so of other rays. He does not see the insect, however, in its true direction, *a*, *c*, *e*, but it appears to him to be at *d*. For we always judge of the place of an object by the direction in which the rays from it strike the eye.

434. When light passes from one medium into another which presents a convex or concave surface, instead of a flat one, a very great change is produced in the direction of its rays. Thus suppose, as represented in Fig. 157, three diverging rays coming from a point, *a*, through the air, enter a *convex* surface of glass, *b*, *b′*. The central ray *a*, *c* enters the glass in a direction perpendicular to its surface, and therefore does not bend from its course. But the ray *a*, *d* enters very obliquely, and is bent towards the perpendicular at that point, *e*, and passes on in the direction *f*. So likewise the ray, *a*, *g*, is bent towards the perpendicular *h*, and passes on in the line *i*. These rays *diverging* in the air have become converging in the glass, and the point at which they meet is called the *focus*. To this point all the other rays entering the convex glass converge also.

435. But if the surface of the glass be *concave*, as represented

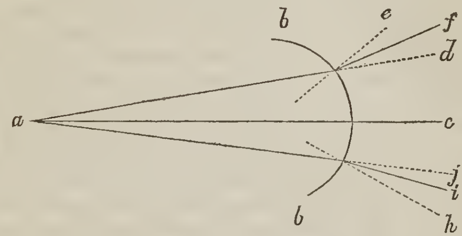
Refraction by convex and concave lenses.

FIG. 157.



in Fig. 158, the diverging rays which enter it will be made to diverge still more. The ray, *a*, *c*, being perpendicular to the surface is unchanged in its course; but the ray, *a*, *d*, is bent towards the perpendicular, *e*, into the line *f*, and the ray, *a*, *j*, is bent towards the perpendicular *h* into the line *i*. In the case of both

FIG. 158.

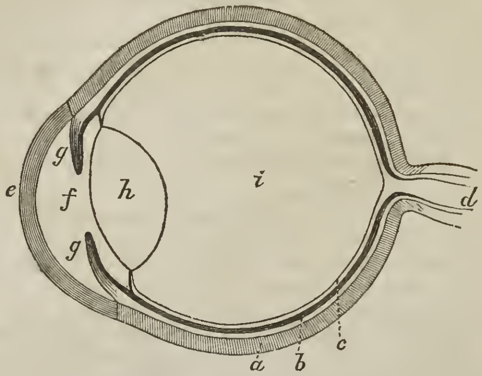


the concave and the convex lens, the greater the curvature, the greater is the change of direction in the rays. The greater the curvature, therefore, the sooner are the rays brought to a focus in the case of the convex lens.

There are other optical principles illustrated in the apparatus of vision, that will be brought out in the description of the eye, which I will now proceed to give.

436. The arrangement of the different parts of the eye you can understand by Fig. 159, which is a mere map of a section of the eye, through its middle part from front to rear. It is intended merely to represent the arrangement of the parts distinctly, without strict regard to proportion. The eye has three

FIG. 159.



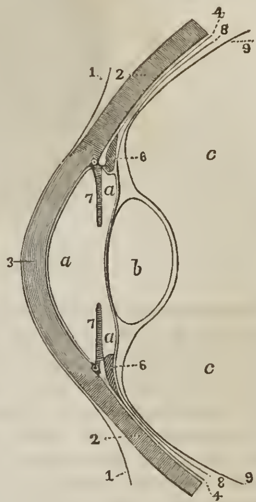
DIFFERENT PARTS OF THE EYE.

coats, as they are called. At *a* is the thick strong white coat, called the *sclerotic* coat, from a Greek word meaning *hard*. This, which is commonly called the white of the eye, gives to the eyeball its firmness. Into it the *cornea*, *e*, fits, like a watch-glass into its case. The sclerotic and cornea then make one coat of the eye, the outer one. Next comes the *choroid* coat, *b*. This is a very vascular coat, containing the minute branches of blood vessels which nourish other parts of the eye. It is of a dark color, for reasons which I will state in another place. Its color is owing to coloring matter contained in pigment cells, which lie along on the inner surface of this coat, next to the inner coat of the eye, the *retina*, *c*. The retina is a thin membrane, being principally composed of the expansion of the optic nerve, *d*. The eye has three *humors*, as they are termed. The first is the *aqueous* or watery humor, *f*, which is in a chamber between the transparent cornea, *e*, and the *crystalline humor*, or lens, *h*. This chamber is divided into two parts by the iris, *g*, *g*, the pupil being the circular communicating door between them. The part of the chamber which is in front of the iris is much larger than that which is behind it. The crystalline humor, or *lens*, as it is more often called, has the consistency of half dissolved glue. At *i* is the *vitreous* humor, filling up a large part of the cavity of the eye. It is called vitreous from its glassy appearance. It is a clear, jelly-like substance, having about the tenacity of white of egg. It is contained in an ex-

ceedingly thin and delicate sac, and this is divided into cells which contain the liquid.

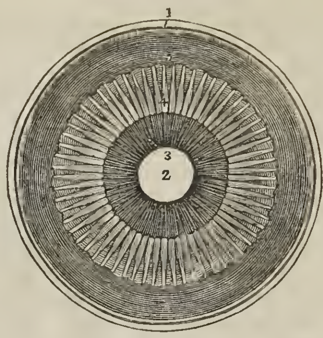
437. Fig. 160 is a map of the front part of the eye, in which the parts are more minutely delineated than in Fig 159. At 2 is the sclerotic coat; 3, the cornea; *b*, the crystalline lens; *a*, *a*, *a*, the aqueous humor; 7, 7, the iris; 4, the choroid coat; 8, the retina; *c*, *c*, the vitreous humor, and 9, the sac containing it. Around the inside of the chamber containing the aqueous humor is a very thin membrane, (represented as you see by a line,) which secretes the humor. In this membrane, as in the case of every other closed sac in the body, there are both exhalents and absorbents, so that the fluid may be changed as necessity requires. There is another thin membrane of the eye which I have not yet described. It is represented by a line, 1, in the figure. It is the *conjunctiva*, so called because it unites or *conjoins* the ball of the eye with the eyelids. It covers the cornea, passes back a little way on the white of the eye, and then turns forward to line the eyelid. It is the seat of the most common form of inflammation in the eye. It is very vascular, as is shown by its distended vessels when it is inflamed. It is exceedingly sensitive, and hence the great pain which is occasioned by any thing, even the smallest mote, that gets into the eye. The object of having it so sensitive I have spoken of in the Chapter on the Nervous System, § 242.

FIG. 160.



438. At 6 in Fig. 160, is one of the *ciliary* processes, as they are called, from their resemblance to the eyelashes. There is a circular row of them, numbering from sixty to eighty, so arranged as to resemble the disk of a radiated flower. In Fig. 161 they are represented as they appear in looking at them from behind, the back part of the eye being removed. At 1 is the divided edge of the three coats; 2, the pupil; 3, the iris; 4, the ciliary processes. At 5 is the anterior edge of the retina,

FIG. 161.



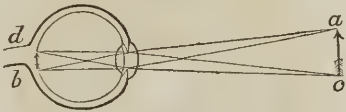
CILIARY PROCESSES.

which stops at the beginning of these processes, presenting, as you see, a scalloped appearance. The processes, however, do not arise from the retina, but come from the choroid coat, and are united at their origin by a ring of ligamentous substance to the sclerotic coat. The exact operation of this beautiful arrangement is not known, but it is pretty well ascertained, that muscular fibres are so connected with these processes, that when they contract they draw the crystalline lens forward. This, as you will see in another part of this chapter, is a very important movement in the adaptation of the eye to seeing at different distances.

439. The object of all this apparatus, which I have described, is to have images of objects formed in the back part of the eye upon the retina, so that the optic nerve expanded there may carry impressions from them to the brain. This is done in this way. The rays of light coming from an object pass through first the cornea, then the aqueous humor, then the crystalline lens, and lastly the vitreous humor to the retina, where they, so to speak, daguerreotype the object. The fact that such an image is formed has been often proved by observation on the eyes of animals. If the eye of a rabbit be cleansed from the fat and muscles at its back part, and a candle, be held in front of it, you can see the image of the candle through the sclerotic coat, formed upon the retina. So if you take the eye of an ox, and carefully pare off the back part, so

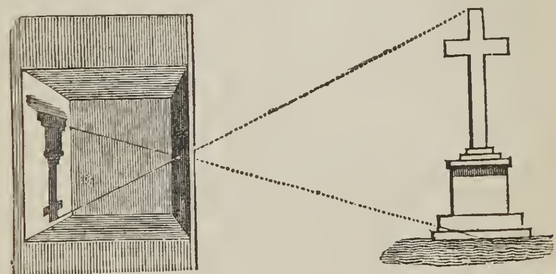
as to leave it very thin, a distinct image of any thing placed in front of the eye may be seen at the back part. The image however will be inverted, as represented in Fig. 162. For the

FIG. 162.



sake of clearness two rays only are represented as coming from each of the two ends of the object, *a*, *c*. These rays cross each other in the middle of the eye, those from *a* being brought to a focus at *b*, and those from *c* at *d*. As all the other rays, coming from other points in the object, are refracted in the same manner, a complete *inverted* picture of it is thus formed. The same thing is seen in the instrument called the *camera obscura*. If light be let into a darkened room through a small aperture in a window shutter, an inverted picture of objects without can be seen on a screen, as represented in Fig. 163.

FIG. 163.



This experiment, which can be performed by any one, illustrates in a rude way the principle of the camera obscura. The real instrument has a tube with a double convex lens, so as to collect together the rays from objects, and concentrate them upon a small space, thereby making a very distinct small image of them. The eye is a very beautiful and perfect instrument of this sort. The space filled by the vitreous humor is the darkened room; the pupil answers to the hole in the window shut-

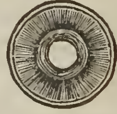
ter, or the tube of the more perfectly constructed camera; the crystalline humor is the lens; and the retina is the screen on which the images are formed.

We will now attend to the agency which the different parts have in producing the result, for which the apparatus is constructed, observing the perfect adaptation of each of them to the particular part which it performs in the process.

440. The cornea, as it lets in the light, requires to be transparent, and, as it is very much exposed to injury, it also requires to be very firm and hard. Both of these objects are secured in an admirable manner. Its transparency is secured in this way. It is made of different layers, which are kept moist by a delicate transparent fluid. It is this which in health makes the eye so clear and sparkling. Disease often so lessens it, as to give this window of the eye a dull appearance. The cornea is, as you see by Fig. 159, more convex than the sclerotic coat, so that it may act with some power as a lens in making the rays converge.

441. The iris is a circular curtain with a round opening in its centre, the pupil, which can be varied in size to a considerable degree. On the iris depends what is called the color of the eye, which is various, as blue, nearly black, grey, hazel, &c. The color is owing to the pigment which is in cells on its inner surface. The chief office of the iris is to regulate the quantity of light that enters the eye. When the light is obscure the opening in the iris is widely dilated; but when there is much light it is contracted; and if the light be excessive, it is contracted almost to a point. Its motions, therefore, considering its small extent, have a very wide range. You can realize this if you look at the eye of some one in a dim light, and then suddenly bring a lighted candle very near to it. These motions are effected by a peculiar arrangement of muscular fibres, of which the iris is in part composed. There are two sets of fibres, the circular and radiated, as represented in Fig. 164. When the circular fibres contract, the pupil is contracted; and when, on the other hand, the radiated fibres contract, the pupil is dilated. There must be a very nice adjustment of the fibres, to enable them to dilate the pupil as widely as they sometimes do, without producing any puckering of the surface of the iris. The opening in the iris is always round in man; but in animals whose range of vision requires to extend widely in

FIG. 164.



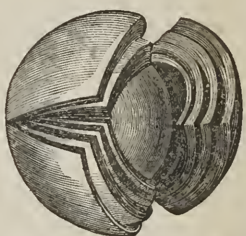
a horizontal direction, (as the herbivorous animals,) it is in the form of an ellipse, with the long diameter horizontal. In animals, on the other hand, that leap up and down in pursuit of their food, as the cat and other carnivorous animals that seek their prey in the same manner, the pupil has the elliptical form, but with the long diameter vertical.

442. The crystalline lens is the chief agent in the eye in concentrating the rays of light by refraction. In Fig. 165 you have a side view of it. Its anterior part, 1, is less convex than its posterior, 2. In Fig. 166 is a magnified view of the lens hardened in spirit and cut open, so as to show the different layers of which it is formed. The layers are more and more hard as you go towards the centre. The object of this arrangement and of the peculiar shape of the lens, is not as yet understood. This lens is the seat of the disease called cataract. In this disease the lens becomes opake so as to prevent the rays of light from passing to the retina. There are three ways of getting rid of the difficulty. One is to introduce an instrument shaped like a needle into the side of the eyeball, with which the opake lens is pushed off one side in the vitreous humor, so as to be out of the way of the rays of light. Another is to break up the lens with the needle, so that its fragments may be absorbed. The third method is to make an opening in the cornea, and to extract the lens through it.

FIG. 165.

Crystalline Lens.

FIG. 166.

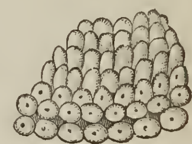


443. The choroid coat (*b*, Fig. 159) contains quite a large share of the minute bloodvessels, and nerves of the eye, and serves for a medium by which they pass to other parts of this organ. But it serves another important purpose by means of its dark pigment. It makes a dark chamber of the back part of the eye where the optic nerve is expanded. The object of this is to secure distinctness in the images formed upon the retina. If the choroid coat were of a light color, there would be so much reflection of the rays of light back and forth in all directions in the eye, that the pictures formed upon the retina would be confused. There would be a glare of light, such as we experience in a room where the walls are all of a very light

color. There is the same reason for having the chamber of the eye of a dark color, as for having that of the camera obscura so. In the albino there is a deficiency of the pigment of the choroid; and, therefore, in a bright light there is in his case a defect of vision, from the cross reflection to which I have alluded. During the day his vision is very indistinct; and it is only when twilight appears that he can see well, or with comfort. The pigment is also deficient in the *iris* of the albino; and the bright red or pinky hue of the iris in his case is owing to the blood in the minute bloodvessels, with which this part is so well supplied. Those animals that use their eyes mostly in daylight have the pigment of the choroid of the darkest color; while, on the other hand, those that need to see most clearly at night, as the owl, either have none of this pigment, or have it of a very light color.

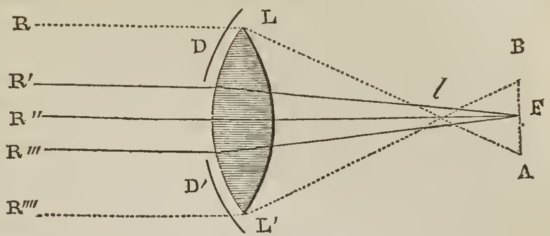
444. The retina is a soft greyish delicate membrane, formed chiefly of the expansion of the optic nerve. Here the images are formed, and the minute fibres of nerve in this membrane receive impressions from these images, which are transmitted to the brain by the trunk of the nerve. This nerve has the same relation to light that the nerve of hearing has to sound, the nerve of smell to odors, or the nerve of touch to the qualities of bodies that we feel. And it is curious to observe that the termination of the nerve of sight on the surface of the retina is arranged in *papillæ*, just as the terminations of the nerves of touch are. In Fig. 167 is represented a portion of the retina of a frog magnified three hundred times. The upper rows of papillæ, which are without dots, are seen sideways.

FIG. 167.



445. The superiority of the eye, as an optical instrument, is seen in a striking manner in several particulars, in which difficulties and defects to which all optical instruments are liable are removed. There is, for example, a defect in the operation of lenses in optical instruments, which is termed *spherical aberration*. This can be explained on Fig. 168, which represents a lens, L, L′, with some of the rays as they pass through it. Now the rays R, R″, R‴, are brought to a focus at F; while the rays R, L and R⁗, L′ come to a focus much nearer, at *l*. It was found by experiment, that if the central portion of the lens be covered, so that the rays R′, R″, R‴, cannot pass, a distinct image will be formed on a screen

FIG. 168.



put at *l*. And, on the other hand, if the outer portion of the lens be covered, so that the outer rays are intercepted, then the middle rays, R′ R″ R‴ will form an image on a screen at F. But if the whole lens be used, no distinct image is formed, wherever you may place the screen. If you place it at *l*, it will receive with the rays that come to a focus there, rays that have their focus at F. And so of other points.

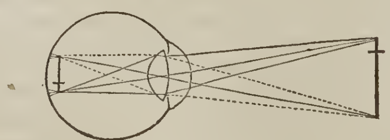
446. It is in view of such experiments, that a contrivance has been adopted in the construction of telescopes and microscopes, for the purpose of remedying the difficulty above described. What is called a *diaphragm*, or *stop*, is put in against every lens. It is a perforated partition which permits the light to pass only through the central portion of the lens. The lines D, D′, in Fig. 168, cutting off all rays in the neighborhood of R and R⁗, show the operation of the *stop*. In the eye the iris acts as the diaphragm or stop to the crystalline lens which is behind it, as you can see by recurring to Fig. 159. Ordinarily, by means of this stop, the rays pass through only the central part of the lens.

447. Another difficulty attending the operation of a common lens is what is termed *chromatic aberration*. Every ray of white light consists of a mixture of rays of seven different colors. Some of these colors are more easily refracted than others, and therefore on passing through a lens will come to a focus sooner. This of course is apt to make some confusion in the color and the distinctness of objects, when seen through a single lens, or through several if they are alike. The difficulty has been remedied, although Sir Isaac Newton thought that it never would be. And it is said that the hint of the remedy was taken from the arrangement of the eye. At any rate, the defect is avoided

by having lenses made of different materials, just as is the ease in the eye. Thus if two lenses be used, one of which is made of flint and the other of eommon glass, the difficulty disappears. In the eye it is perfectly avoided by the passage of the rays through so many different materials, before it reaehes the retina. The *stop* has been found a partial remedy in the ease of optical instruments; and the iris, the stop of the eye, of eourse acts in the same way. But the full remedy was not found, till another step was taken in imitation of the eye, the most perfect of all optical instruments.

448. There is another arrangement in the eye, whieh the optieian can imitate only in a comparatively bungling manner. It is that by which the eye adapts itself to different distances in looking at objects. If we look through a telescope at a near object, and then turn it towards one at a distance, we cannot see it distinctly until we adjust the lenses to suit the distance. But in the eye how quickly the adjustment is made! It is done ordinarily, without any effort on our part of which we are conscious. It is done so easily that we do not think of the change. We look at an objeet at a few inehes distance, and in an instant turn the eye and see an objeet afar off with almost equal distinctness. There has been much discussion in regard to the means by which this adjustment is effeeted. One of the means undoubtedly is, a change in the relative position of the crystalline lens, which is effeeted by the museular fibres spoken of in § 438. These fibres when they contract, draw the lens towards the front of the eye, and away from the retina. This is done whenever we look at a near object. If it were not, the rays which come from the object, as they diverge eonsiderably, would not be brought to a foeus when they reach the retina. The iris also has some agency in adjusting the eye for seeing at different distances. When the eye is turned to a near object the pupil always contracts, thereby shutting out those rays coming from it whieh are the most divergent.

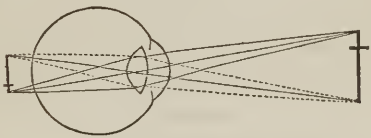
FIG. 169.



449. In some cases this power of adjustment is counteracted by defect in the arrangement of the eye. Thus, in the *near-sighted*, either the cornea or the crystalline lens, or both, are too convex; or, the crystalline lens is too far from the retina. The result is, that the rays of light coming from a distant object come to a focus before they reach the retina, as represented in Fig. 169. All objects, therefore, are seen indistinctly except those which are brought near to the eye. This defect is remedied by the use of a concave lens, which counteracts the effect of the too highly refractive power of the eye by making the rays divergent, instead of parallel, before entering the eye. By an habitual adjustment of the eye for seeing near objects, near-sightedness may be produced. Hence it is that engravers, watch-makers, students, &c., are so liable to become near sighted.

450. In the far sighted the difficulty is of an opposite character. The refractive power of the eye is too feeble. This is owing either to too little convexity of the cornea, or of the crystalline lens, or of both; or, to too great nearness of the crystalline lens to the retina. In this case the rays coming from a near object do not come to a focus soon enough. The focus of the rays coming from any point of the object is behind the retina, as seen in Fig. 170, in which the rays from two

FIG. 170.



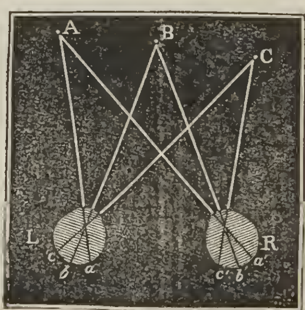
points are represented as prolonged till they meet at their focus behind the retina. This defect is palliated by the use of convex glasses. It is quite common in persons who have passed middle age; while near-sightedness appears mostly in younger persons, the full compliment of the humors of the eye in their case making the front part of the organ prominent.

451. There has been much discussion of the question why we see every thing in its real position, while the images of objects are, as you have seen in § 439, reversed on the retina. It has been supposed by some that we really see every thing reversed, and that our experience with the sense of touch, in connection with that of vision, sets us right in this particular.

And this, it is supposed, is the more readily done from the fact, that our own limbs and bodies are reversed as pictured on the retina, as well as objects that are around us, so that every thing is *relatively* right in position. But if this be the true explanation, those who have their sight restored, after having been blind from birth, should at first see every thing wrong side up, and should be conscious of rectifying the error by looking at their own limbs and bodies. But this is not so. In the case related by the anatomist Cheselden, of the boy who was blind from birth, and who at about the age of thirteen had his sight restored by an operation, there was no complaint that he did not see things erect at the first. If this difficulty had existed, he would have complained of it quite as readily as he did of the difficulty in estimating the size and the distance of objects. The above explanation of erect vision, and other explanations of a similar character, are based upon a wrong idea of the office which the nerve performs in the process of vision. It is not the image formed upon the retina which is transmitted to the brain, but an impression produced by that image. The mind does not look in upon the eye and see the image, but it receives an impression from it through the nerve; and this impression is so managed that the mind gets the right idea of the relative position of objects. Of the way in which this is done we know as little as we know of the nature of the impression itself.

452. It is an interesting and wonderful fact, that as we look at an object with both eyes, although there are two images formed, and therefore two impressions are carried to the brain by the two nerves, yet a single impression is produced in the

FIG. 171.



mind. To produce this single effect at the end of the process of seeing, it is manifest that there must be a very exact correspondence in the two eyes as optical instruments. The two images must be similar, and must be formed on corresponding parts of the retina in both eyes. Thus, if there be a range of objects, as at A, B, C, in Fig. 171, the impression will be a single one in the mind, because the picture of these objects is on the same part of the retina in both eyes, a, b, c, and a', b', c'. But if you press with your finger one of the eyes a little out of its place, all these objects will appear double, because their images occupy different parts of the retina in the two eyes.

453. It is essential, therefore, that the muscles which move the eyes, as we direct them towards different objects, should harmonize in their action. They must move together with great exactness, or there will be disarrangement of vision. If the want of correspondence be slight, the vision will be merely confused. But if it be considerable, so that the images are formed on quite different parts of the retina, in the two eyes, every object will be distinctly double. You can verify this, by pressing one of your eyes with the finger with different degrees of force, while you look at the objects. The intoxicated man often sees indistinctly, and sometimes even double, from this want of correspondence in the action of the muscles moving the eyes. This is one of the causes of double vision, as we see it occurring in disease. I will cite a case which has recently come under my care, in illustration. The patient could see as usual, so long as he looked directly in front, or towards the left. But when he turned his eyes to look towards the right, he saw every thing double, and the farther he looked in that direction, the farther apart were the two images of every object. The reason was obvious. In looking to the right, the left eye turns towards the nose, while the right eye turns from it outward. The failure in this case was in the action of the muscle that turns the right eye from the nose. The consequence was, that as he attempted to turn his eyes to look to the right, the right eye did not correspond in its motion with the left, but remained nearly stationary, presenting therefore a squinting appearance. In common squinting, there is a permanent contraction of one of these straight muscles, similar to that which we see in wry-neck, as stated in § 308. When this difficulty exists, the images of objects are formed in two different parts of the retina in the two eyes, as in the case which I have just related. We should therefore expect that there

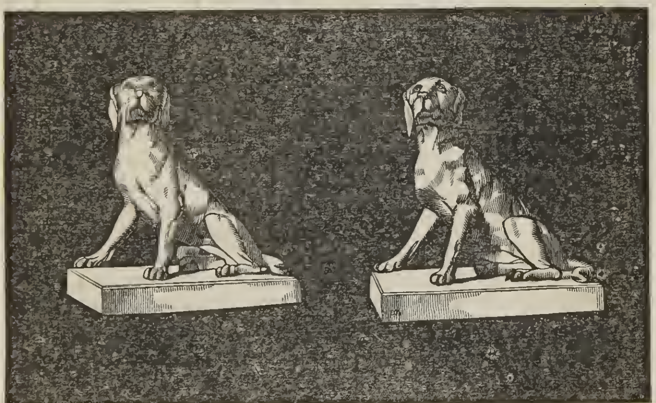
would be double vision, but ordinarily there is not. Why is this? It is because the mind acquires the habit of attending to the impression that comes from one eye alone, the sound one. If the squinting occur suddenly there is double vision at first, because it takes a little time for the mind to acquire the habit referred to. But it generally comes on gradually, and therefore there is no difficulty in the acquisition of this habit, to meet the exigency of the case.

454. While it is necessary to single vision when both eyes are used, that the image of the object should occupy corresponding portions of the retina in the two eyes, it is not true that these two images are in all cases exactly alike. They are so when the object presents a plane surface, or one, every line of which can be seen equally well by both eyes. But if the object be such that some lines or surfaces of it are seen by one eye alone, while other lines and surfaces of it are seen only by the other eye, two different images are obviously formed in the two eyes. You can verify this by a simple experiment. If you hold a book before your eyes, with its back in a vertical direction, you see the back of the book and its sides at once, as a single object. If now, still holding the book in the same position, you shut one eye, you see but one side of the cover of the book—that one which is on the same side with the open eye. And so with the other eye. The plain inference is, that when you look at the book with both eyes, the image formed in the right eye is composed of the back of the book and the cover of the right side, while the image in the left eye is composed of the back of the book and the cover of the left side. From these two distinct images, of course, two distinct impressions are sent to the brain; and yet but a single impression is recognized there by the mind, for the book is seen as a single object. This single impression must, therefore, result in some way from a mingling of the two impressions transmitted along the two optic nerves. Were it not for this mingling of the two impressions, we should see double, that is, see two things, whenever we look at any solid projecting object, and should see single only when we look at plane surfaces. Indeed, one who has but one eye can not acquire from sight alone any idea of solidity. Every thing would appear to him to be on a plane surface, till he finds it to be otherwise by the use of the sense of touch, in connection with that of sight.

455. The statements in the last paragraph are beautifully illustrated by the instrument contrived by Professor Wheatstone,

which he calls the stereoscope. In using this instrument, you look at two pictures of the same object with the two eyes, and yet you see but one thing—that is, but one impression is produced in the mind, although two different pictures are made in the two eyes, and of course two different impressions are conveyed to the brain. Suppose the object represented is a book, as described in the experiment alluded to, in § 454. In the right half of the instrument is a representation of the book, as seen by the right eye, and in the left half is a representation of it as seen by the left eye. As you look at them you see but one book, just as you do in holding the book before your eyes. The two different images formed in the two eyes are the same in the two experiments. The same thing is done with other objects. Thus, the two representations of a dog, seen in Fig. 172, are seen in the instrument as a single dog. You observe

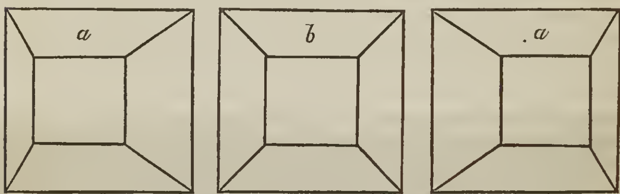
FIG. 172.



that they are shaded differently. They are representations of the two pictures, which a dog in this position would make on the retina in both of the eyes of a person looking at him. When you look at them in the instrument, the single dog that you see stands out more than either of the two representations, as seen when they are not in the instrument. The reason is obvious. In the two images formed in the eyes, as you look into the instrument, are all the lines of light and shade, which

you would see in looking at a real dog with both eyes; while either one of these representations contains only a part of these lines. You can imitate in some good degree the effect of the stereoscope, by placing the end of a small book between these figures, and letting the other end rest against the nose and forehead, thus separating the eyes from each other. If now you look intently at the two figures, you will in a few moments find them approximate each other, till at length they mingle together, and you will see but a single dog standing out like a statue. The same thing can be shown by mathematical figures. Thus, if two figures *a a*, represented in Fig. 173, be placed in

FIG. 173.



the two apartments of the instrument, on looking into it you will see a single figure, shaped like *b*. You can imitate the stereoscope here also, by placing the end of a book in such a way as to cover the middle figure, the other end being between the eyes. The two figures will run together, and the union will represent the figure of a truncated, four-sided figure, standing out in bold relief. But such experiments afford only a rude imitation of the stereoscope, for in this instrument the separation between the eyes is entire, so that the effect is produced at once. There is no running together of the two figures, but the moment that you look into the instrument they are blended in one.

456. The harmony which we have seen to exist in the action of the eyes is very wonderful. It must be remembered that the eyes are optical instruments, endowed with self-adjusting powers, to accommodate the different distances of objects, and the varying degrees of light. And thus must both be just alike in all these diversified adjustments, that the images in both may correspond. And besides all this adjusting machinery inside of the eyes, so delicate and so correspondent in its action in both, there is muscular machinery outside, to move the eye-

balls in all directions; and in these movements also, as you have seen, there is an exact correspondence. All these motions for adjusting this complicated machinery within and around the eyes, are regulated by the nerves. How astonishing the accuracy with which they do this! How exact are the different impressions transmitted through them, in producing the various degrees, and multiplied combinations of action, in the little muscles of these organs!

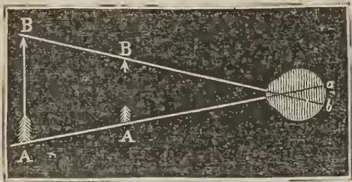
457. There is correspondence not only in the machinery of the eyes, as optical instruments, but also in that portion of the process of seeing which is not mechanical. The nerves of vision must be exactly correspondent in the two eyes, that similar impressions may go from the retina to the brain in both. And the correspondence is in this case the more wonderful from the fact, that the impressions transmitted are, as you have seen, not always precisely alike. How the harmony is preserved in connection with this variation is a great mystery. We can readily conceive how a single impression can result in the mind, from two impressions transmitted to the brain from two images which are exactly alike. But we cannot conceive how confusion can be avoided when the images and the consequent impressions are in some measure different. In this connection I will notice a peculiarity in the arrangement of the optic nerves. They are not entirely separate as they go from the eyes to the brain. At one point in their course they unite together, and then separate again. In doing so, some fibres from both the nerves communicate together, and some cross each other, so that a portion of each nerve passes over to the other before they go to the brain. Undoubtedly this arrangement has some reference to the harmony of action of the two nerves, but we know nothing of the way in which it exercises its agency in this respect.

458. The power of perceiving the size, distance, and figure of objects, is wholly an acquired power. The case already referred to, in which Cheselden restored the sight by an operation, shows this to be true. "When he first saw," says Cheselden of his patient, "he was so far from making any judgment about distances, that he thought that all objects whatever touched his eyes (as he expressed it,) as what he felt did his skin, and thought no objects so agreeable as those which were smooth and regular, though he could form no judgment of their shape, or guess what it was in any object that was pleasing to him. He knew not the shape of any thing, nor any one thing from

another, however different in shape or magnitude; but upon being told what things were, whose form he before knew from feeling, he would carefully observe, that he might know them again; but having too many objects to learn at once, he forgot many of them; and (as he said), at first he learned to know, and again forgot a thousand things in a day. At first he could bear but very little light, and the things he saw he thought extremely large; but upon seeing things larger, those first seen he conceived less, never being able to imagine any lines beyond the bounds that he saw; the room he was in, he said, he knew to be but part of the house, yet he could not conceive that the whole house could look bigger." Every infant, if it could express its ideas, could give us a narrative of a similar experience, in its first lessons in seeing. It is obvious that seeing is a process which we learn to do, as really as we learn to talk or walk. The confused vision of the infant bears the same relation to the accurate vision of the adult, that its uncouth noises and awkward motions bear to the adult's harmonious utterances and graceful movements. In order to acquire definite and correct ideas of objects, we are obliged to learn how to use those optical instruments, the eyes. The infant manifestly does not know how to use them to any great advantage. He does not at first know how to use the muscles that direct the eyes towards any object, and there is, therefore, an obvious awkwardness in their movements. As he reaches out his hands towards objects, it is plain that he does not appreciate their distances. He reaches out for the moon, or any other distant object, just as he does for the toy that is held before him. It is by a continued comparison of experiences that he learns the sizes, shapes, and distances of objects. And in doing this, the sense of touch acts as the educator of the vision, very much, as the ear educates the voice. And even the adult, with all the training which he has bestowed upon his eyes, often makes mistakes, especially in relation to magnitude and distance. There are various degrees of skill in seeing; and he is the most skillful seer who makes the fewest of the mistakes referred to.

459. Let us look now at the means by which we gain the experience that is necessary to correct vision. One means is the appreciation of the space occupied by objects in the field of vision. This is measured by what is termed the *visual angle*—that is, the angle which is formed by two lines coming from the extremities of an object, and meeting in the eye, as represented in Fig. 174. In this way we get the idea of mag-

FIG. 174.



nitude. But it is manifest that it cannot alone give us this idea correctly. It would do so, if all objects were at an equal distance from the eye. But you can see by the figure, that if they are at different distances, you must know something of those distances, to estimate the magnitude of the objects by the visual angle, which they subtend. The arrow at A, B will appear just as large as the larger one at A′, B′, because it will occupy the same space a, b on the retina, and subtend the same angle. But if you know that the one is nearer to you than the other, you make allowance for this in the estimation of the size. Your hand, held up to keep the rays of the sun from your eyes, would look to you as large as the sun itself, if you did not know how near it is to you; and the sun and moon appear to us to have about the same magnitude, because we do not keep in mind the fact that the sun is ninety-six millions of miles from us, while the moon is only two hundred and forty thousand.

460. Another means which we use in getting a correct idea of objects by vision, is the degree of distinctness in their lines, and shadows, and colors. The fact is learned very early by the child, that the nearer objects are, the greater is their distinctness; and he makes use of this fact continually in estimating both their distance and their magnitude. He estimates the latter less directly than he does the former by this means. He makes use of his notion of the distance of an object, gained by its degree of distinctness, in forming an idea of its magnitude. Many mistakes are made in the use of this means of judging of objects. Thus, a very bright light will often appear to be nearer than one that is less bright. When the atmosphere is very clear, mountains and other objects appear nearer to us than they do when the atmosphere is thick and hazy.

461. Another means of making a correct estimate of the distance and magnitude of objects is, comparison with other

objects which are familiar to us. Thus, we get our ideas of the size of animals from objects in their neighborhood. The artist makes use of this means of communicating ideas of size in pictures and engravings. Figures of men are placed near large buildings for this purpose. A notion of the great size of the elephant is given by placing his keeper at his side. I need not multiply instances of this sort. We are not ordinarily aware how dependent we are upon such comparisons, in estimating the magnitude of objects. An occasional mistake reminds us of it however. For example, I once turned my eye suddenly from a giddy height, upon some huts below at a river's side; they appeared to me to be dog kennels, till a man issued from the door of one of them, and thus dispelled the illusion, by affording me a means of comparison. So complete was the illusion, and so sudden was the dissipation of it, that it seemed as if there was an instantaneous swelling of dog kennels into huts. Every one must have noticed how large the full moon appears as he sees it rising, while the higher it rises the smaller it becomes to the eye, although it is really at no greater distance than it was when it first rose. The reason is, that when it first rises you see it in a range with other objects, with which you instinctively compare it. And, therefore, it appears larger when you see it rising in the direction of some distinct object, as a large building, or a high hill, than it does when you see it rising over a level plain.

462. Another means of judging of the magnitude and distance of objects is, the *muscular sense* (§ 323) exercised in adjusting the eyes in seeing them. Thus, consciousness of the amount of muscular action, in passing the eye up and down a tall object, helps to give us an idea of its height. So too, in looking at near objects, consciousness of the amount of effort, in turning the two eyes towards the point looked at, helps us to estimate the distance of the object. Commonly we do not distinctly think of this effort, because it is so easily made; but, if after looking at an object held at some distance from the eyes, we suddenly bring it very near, the effort to make the axes* of the eyes converge enough to see it distinctly is very manifest, producing a straining effect, which, if it be repeated many times successively, wearies the eyes. You can discover how very dependent you are upon this sense of the convergence of the

* The axis (plural axes) of the eye is a line drawn through the centre of the cornea and pupil backward through the eye to the central point of the retina. In Fig. 171 the axes are B b, and B b'.

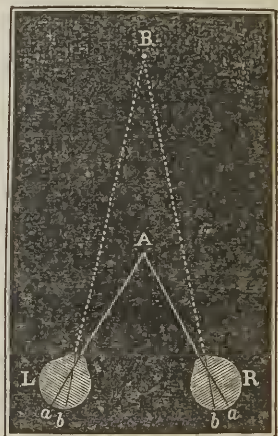
eyes, in accurately estimating comparative distances in near objects, by attempting to thread a needle, or nib a pen, or snuff a candle with one eye shut. The change in the convergence of the eyes, on looking at objects at different distances, is very manifest to us when we observe the eyes of others. We perceive thus not only the direction, but the distance of the objects at which they are looking. We do this so continually from our infancy, that we very early acquire great accuracy in judging, at what distance the point is towards which the eyes are turned, or in which, in other words, the axes of the eyes meet.

463. From the facts presented in the few last paragraphs, it is obvious that what we include in the word seeing is, to a great extent, a mental process. That is, there are certain mental efforts which are absolutely essential to correctness in vision. Without these mental efforts or processes, we could not see things as they are, as it is expressed very properly, but we should see them as the boy operated upon by Cheselden did, when he first began to see. Seeing is commonly supposed to be a very simple process. The idea is, that one has merely to open his eyes, and he sees. But, as you have seen, the whole process is both a complicated and a difficult one; and in order to be able to do it, the eyes have to go through a course of training in the case of every infant, just as was the case with the boy whose sight Cheselden restored. We should be conscious of this, if we could recollect the experiences of infancy. But not being able to do this, it is only when we make some extraordinary effort in vision, that we are at all sensible that there is any acquired skill in the process. After the training which the eyes have in infancy, ordinary seeing is done with so much facility, that we are not conscious of any effort either bodily or mental. This appears very wonderful, when we consider that the eyes are two optical instruments, which need, as you have seen, a most careful and nice change of adjustment continually, to see in different directions, and at different distances, and that there is also considerable and complex mental effort in getting the right impressions from the objects which are pictured upon the retina.

464. But there is another view in which the mental part of the process of vision appears strikingly prominent. When it is said that images of objects are formed upon the retina, and that impressions are transmitted from them to the brain, this is far from stating all that is true on that point. Many of the images pictured upon the retina do not transmit impressions to

the mind. The sensation of seeing is, therefore, in relation to them incomplete—the beginning only of the process is effected. This you have seen to be true in the case of strabismus or squinting. The faulty eye in this case is not used—the mind takes no cognizance of the images formed in it (§ 453). But it is true of ordinary vision also, that the mind takes no cognizance of many of the images formed on the retina. This can be verified by a simple experiment. If you hold a finger near the eyes (at some ten or twelve inches from them), and a finger of the other hand at a greater distance, but in the same direction, and then look at the near finger, you will perceive that the other finger appears double. So, on the other hand, if you look at the distant finger, the near one appears double. The reason of this can be made clear to you by Fig. 175. The two eyes, L and R, being directed so that their axes converge on the object A, the middle points of the two images correspond with the middle points of the retina in the two eyes, *a* and *a′*. The images thus corresponding in their place on the retina, the impressions carried from them by the two optic nerves to the brain correspond also, and so the vision is single. But the image of the object B is formed in the two eyes, in parts of the retina that do not correspond, *b* and *b′*. They are both on the *inside* of the middle points, *a a′*, that is towards the nose; whereas the outward part of the retina in one eye corresponds with the inward part in the other eye, and vice versa. This you will see to be true by recurring to Fig. 171, in which is shown the way in which a row of objects is pictured on the retina in the two eyes. There you see that the image of the object A, for example, is in the left eye, L, on the *inner* side of the middle point, *b* of the retina; while in the right eye, R, it is at the *outer* side of the middle point, *b′*. In the case of the object B, then, in Fig. 175, it is clear to you that the images of it in the two eyes are

FIG. 175.



formed in parts of the retina that do not correspond, and therefore it appears double.

465. The application of all this to the point in hand you can readily see. As the images of all objects in the field of vision of the two eyes are pictured on the retina, it is plain, according to the facts developed above, that whenever the eyes are directed together to any one object, other objects in the same direction, but at a different distance, must make images on the retina in the two eyes that do not correspond. We are therefore continually seeing double, so far as that part of the process of seeing, which consists in the formation of the images, is concerned. But we are not ordinarily conscious of seeing double. How is this? How is the difficulty (for it is a real difficulty in the eyes, as a pair of optical instruments, arising from the non-corresponding images) remedied? It is done obviously in the other part of the process of seeing, the mental part. The mind regulates vision by the varying degrees of attention it bestows on objects. Ordinarily it does not attend to non-corresponding impressions that come from the non-corresponding images, but it attends only to those which are correspondent. As in squinting, it disregards, as you have seen, the impressions that come from the faulty eye, so in ordinary vision it disregards many of the impressions that come from both of the eyes. By an effort of the will it can attend to the impressions which it ordinarily disregards. When this effort is not made, it disregards them, as we may say, instinctively. To make this obvious, I will recur to the experiment with the two fingers, held at different distances. When you first attempt the experiment, you do not for the moment perceive that you see one finger double, because you change the direction of your eyes from one finger to the other, so easily and so unconsciously, that you seem to see them both singly at once. But by a little mental effort you fix your eyes on one, at the same time attending to the images and consequent impressions produced by the other, and then the experiment succeeds. From all this it is obvious that the reason that you do not see very near objects double, when looking beyond them to distant ones, or see distant ones double when looking at near ones in the same direction, is simply that the mind ordinarily attends only to those images and impressions which are correspondent, while it with an habitual instinct disregards those which are not so.

466. In connection with this subject of the influence of mental attention on vision, it is proper to notice the fact, that vision is most

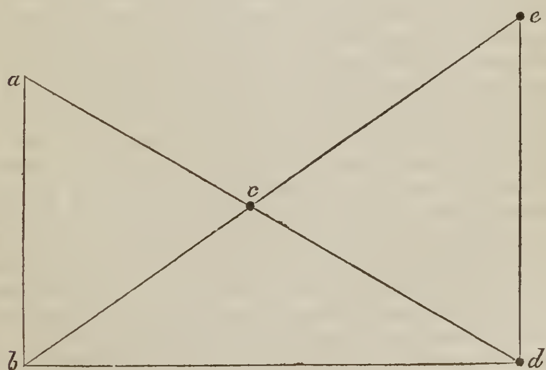
distinct at the central part of the retina—that part where the axis of the eye strikes, as seen in Fig. 171, *b*, *b′*. This is commonly called the *point of distinct vision.* The mental attention makes use of this point continually. Thus, if we are looking intently at a minute object, the eyes are so directed, that their converging axes meet on the object. So when we are reading, although the whole page may be pictured on the retina of each eye, only the letter on which the axes of the eyes meet is seen with perfect distinctness. And the point of union of the axes moves from one letter to another along the lines, so that each letter is successively pictured on the central part of the retina. The process is so rapid that we are not conscious of it, until we take pains to observe what the process is. So, in looking at a prospect, the eyes at each moment see some one point more distinctly than any other part of all that fills the field of vision. We are unconscious of this, just as in the case of reading, because the axes of the eyes are so continually moved by a slight but exceedingly quick motion from one point to another. We in this way take into the central part of the retina so many points with such rapidity, that, by a mingling of the impressions upon the mind, we seem to see the whole prospect at the same moment, with nearly equal distinctness. The successive impressions from the images on the retina, occupy so little time, that they appear to be simultaneous, unless we watch the process.

467. But although some one letter on a page, or some one point in a prospect, is at each moment seen with much more distinctness than what is all about it, yet there is some vision of the page and of the prospect as a whole, of course being less distinct the farther it is from the central point. It is pictured as a whole on the retina, and the impression from it as a whole goes by the nerve to the brain. The picture is a very minute one, as it occupies a small space, and yet it is very distinct in all its lines, and shades, and colorings. On this point Dr. Paley remarks that "in considering vision as achieved by the means of an image formed at the bottom of the eye, we can never reflect without wonder upon the smallness, yet correctness of the picture, the subtility of the touch, the fineness of the lines. A landscape of five or six square leagues is brought into a space of half an inch diameter; yet the multitude of objects which it contains are all preserved; are all discriminated in their magnitudes, positions, figures, colors. The prospect from Hampstead Hill is compressed into the compass of a sixpence, yet is circumstantially represented."

468. We form a judgment of the motion of bodies, in part by the movement of the images of them upon the retina. The perception of this movement must be exceedingly delicate, for even when a body passes over a considerable space, its image moves over a very small space on the retina. "A stage-coach," says Dr. Paley, "traveling at its ordinary speed for half an hour, passes in the eye only over one-twelfth of an inch, yet is this change of place in the image distinctly perceived throughout the whole progress; for it is only by means of that perception that the motion of the coach itself is made sensible to the eye. If any thing can abate our admiration of the smallness of this visual tablet, compared with the extent of vision, it is the reflection which the view of nature leads us every hour to make, viz: that in the hands of the Creator, great and little are nothing."

469. Many of our impressions in regard to motion, as we look at objects, are erroneous. When we are moving ourselves, for example, stationary objects appear to move. As we ride rapidly, the objects that we see seem to fly by us. This is especially the case, if the motion to which we are subjected be an even one, as when we ride in a rail-road car. And if we look at distant and near objects at the same time, while the near objects seem to fly back, the distant seem to go along with us. This is owing to their relative change of position, as can be made clear by Fig. 176. Suppose that when at *a* you see

FIG. 176.



two objects, *c* and *d*, in the same direction. If you pass rapidly to *b*, the object *c* appears to have moved backward in relation to the object, *d*, while the object, *d*, appears to have moved forward in relation to *c*; and the line, *d*, *e*, represents the relative change of positions in the images of the two objects upon the retina.

470. As every object that we see is daguerreotyped, as we may say, upon the retina, the rapidity with which these pictures change, and the distinctness with which the nerves transmit impressions from them to the brain, are very wonderful. The time required for each transmission is very small—only the fraction of a second. The length of time has been estimated by experiment. Thus, if it is found that a burning coal, whirling around at the rate of six times in a second, produces a continuous circle of light, but that the circle is broken when it whirls round only five times in a second, we know that the length of time required for a distinct and separate impression is the one-fifth of a second. The same experiment can be tried with a wheel. In this case we observe what is the largest number of revolutions in a second, that can be made without blending the visual impressions of the spokes into one continuous impression. By such experiments, it has been found that the time required for a distinct visual impression varies in different individuals, and in the same individual at different times, from one-fourth to one-tenth of a second. This difference in the rapidity of succession of the impressions is of course not owing to any difference in the rapidity of the formation of the images; for they are formed by the light, and light always moves with the same velocity. It must be owing manifestly to a difference of facility on the part of the *mind*, in receiving impressions from the images. In other words, the mental activity in the use of the optical instruments, the eyes, differs in different individuals, and in the same individual at different times. If one sees more quickly than another, it is a mental quickness. It is a difference analogous to that which we see in relation to the use of other instruments of the mind, the muscles for example. Some use these instruments much more readily and rapidly than others. We see this in the motions of the eyes themselves, and the eyelids also. Some wink more quickly than others, and there was wisdom in the decision of the blacksmith who dismissed a workman, because he did not wink quick enough, and was therefore always getting sparks in his eyes.

471. The blending of impressions in vision, produced by rapid motion, has been made use of in the contrivance of an amusing optical toy, called the Thaumatrope. In making this, you cut a circular card, and make two different figures on its two sides. If you attach two silken strings to opposite points in its diameter, and then twist the strings, so that when the card is left to go free, it will revolve with considerable rapidity, the two figures will be mingled together as seen by the eye. In Figs. 177 and 178, are represented the two sides of a card,

FIG. 177.

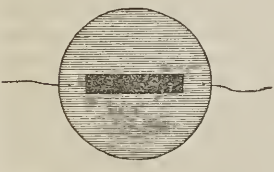
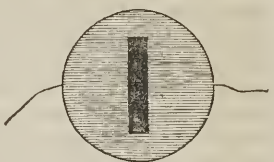


FIG. 178.



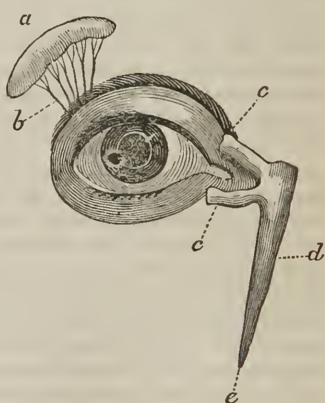
prepared in this way. In this case, the figures as they mingle together appear to the eye as a cross. If a bird be drawn on one side of the card, and a cage on the other, the mingling of the two figures, as the card revolves, will show you the bird in the cage.

There are many other points in regard to the phenomena of vision, which it would be interesting to notice. But it would make this chapter too long.

472. The means by which so delicate an organ as the eye is protected from injury, are worthy of notice. Observe first its situation. Parapets of bone surround it, and receive the force of most of the blows that come upon that part of the face. Above is the strong arch of bone, forming the lower part of the forehead. Then there are the cheek bones, and the bones of the nose. Thus, walled in, in all directions by these prominences, the eye is seldom hurt, except by a direct thrust. And besides being thus protected by surrounding bones, it reposes upon a soft cushion of fat, which yields, if the eye be pushed backward by violence. Indeed it is thus pushed backward effectually by the muscle that closes the eyelids, whenever an impending blow is seen, and it is thus sunk farther back in its cushioned recess, amid the projecting parapets, and of course receives less of the force of the blow than it otherwise would. This muscle, also, by its instantaneous action, prevents many

light articles from flying into the eye. Such articles are also often prevented from entering the eye, by being intercepted by the eyelashes. The *eyebrow*, beside being an ornament, protects the eye from harm, by preventing the salt perspiration from running down into the eye, and irritating it. It acts as a thatched roof, projecting from the arch over the eye, and letting the perspiration from the forehead evaporate from it, when it is small in amount, or drop from it down upon the cheek, when it is abundant. The *eyelashes* also serve to keep the perspiration of the eyelids from entering the eye. The structure of the *eyelids* is such, that the freest motion is allowed, while they afford by their firmness considerable protection to the organ. They derive their firmness from a fibrous cartilage, which makes the body of each lid. You can readily see that this cartilage, making an even pressure on the surface of the eye, must often prove an effectual defense against direct thrusts. If the weapon hit this cartilage, it acts as a firm shield, to ward off the blow from the eye behind it. And even that part of the lid which is intended by its laxness to allow free motion to the lid, the skin, is often an effectual defense. If an impending blow be seen, and the eye be instantaneously and forcibly shut, the wrinkled skin forms a soft cushion over the eye, and thus not only covers it up, but serves materially to deaden the force of the blow.

FIG. 179.



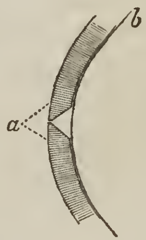
TEAR APPARATUS.

473. The tear apparatus affords the eye material protection. The bland tears keep the organ properly lubricated, so that its constant motions occasion no irritation. And if any thing gets into the eye, the tears are manufactured abundantly, for the purpose of washing out the intruding substance, which is generally effected. Fishes have no need of a tear apparatus, as their eyes are washed constantly by the water in which they live. In Fig. 179 is represented the tear-apparatus. The tears are

secreted by a small gland, called the *lachrymal gland*, situated at *a*, in the orbit under the arch of the forehead, and near the outer angle of the eye. At *b* are the ducts which empty the tears in upon the surface of the eye on the inside of the upper lid. By the constant motions of the organ the tears are diffused over its whole surface, and thus continually wash the eye. The arrangement for carrying off the fluid is this. It flows through a tube, *d*, *e*, into the nose. This tube has at its beginning in the eye two branches, *c*, *c*, which open on the edges of the two lids at the inner corner of the eye. These open mouths, that drink up the tears as they flow to them, you can very readily see. The drain of the eye, which thus conveys the lachrymal fluid to the nose, is ordinarily capable of taking care of all the tears that the gland makes. But when an uncommon amount is made, as in weeping, it cannot receive all the tears, and they therefore overflow their banks, the edges of the eyelids. And sometimes there is a constant overflow from obstruction of the drain by disease. The continual weeping of the eye, when this obstruction exists, will give you some idea of the amount of fluid which the lachrymal glands make.

474. Along on the edge of each eyelid are some very small glands which secrete an oily substance. This serves two purposes. It oils the eyelashes. It also prevents the tears, when they are only in ordinary quantity, from being diffused over the edges of the eyelids in the constant motions of the eye. This exceedingly small quantity of oily substance suffices to keep the tears in the eye where they are needed. There is also a curious provision for directing the tears to the mouths of the ducts when the lids are closed. When brought together their edges unite in such a manner as to form with the surface of the eye a triangular channel for the tears to run in. This is made clear by the diagram in Fig. 180, in which the line *b* represents the surface of the eye, and *a* the edges of the lids, showing a section of the canal between them.

FIG. 180.

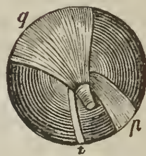


475. I had intended to notice some of the peculiarities of the eyes of different classes of animals, but this chapter is already so long that I will notice but one — the *nictitating membrane* in the eyes of birds. When not in use it is gathered up in the inner corner of the eye. When it is stretched over the organ it is a thin translu-

cent membrane. It is very elastic, so that as soon as the muscles that sweep it so quickly over the eye are relaxed, it flies back at once to the corner where it is so snugly folded. In Fig. 181 it is represented as half way over the front of the eye. In Fig. 182 are seen the curiously arranged muscles that move it. One of the muscles, *g*, arises from the ball of the eye at its upper part, and running back forms by the trunk of the optic nerve a tendon with a loop, through which the tendon of the other muscle, *p*, works. This muscle arises from the lower part of the ball of the eye, opposite to the origin of the first muscle. Its tendon, *t*, is fastened into the edge of the nictitating membrane. It acts through the loop as a pulley, and you can see that the muscle, *g*, assists it materially in effecting the very quick motions of the membrane.

FIG. 181.

FIG. 182.



CHAPTER XVII.

CONNECTION OF THE MIND AND THE BODY.

476. In the Chapter on the Nervous System I gave you a general view of its functions and its arrangements. You saw that it is to the mind the grand means of communication with the world of material and immaterial things around it. In the Chapters on the Senses and the Organs of Locomotion, we have considered the modes in which this communication is maintained, through organs subordinate to the nervous system. And you have seen that through the senses all knowledge of external things is communicated to the mind, where it is used as the material of thought and reflection and feeling; while, on the other hand, through the muscles the mind produces all its impressions upon the things and beings on which it acts. You

are now therefore prepared to look more thoroughly into the connection which the nervous system establishes between the mind and the body, and to observe some of the higher and more intricate phenomena which result from it. It is to views upon these points that I shall devote this and the following chapter.

477. The brain is the organ of the mind. In this life there can be no mental manifestations except through the agency of this organ. The mind and the brain always act together as one thing. This is manifest in regard to motion and sensation. It is equally true of thought. The mind can think and excite motion in the muscles only through the brain. The proofs of this are various and abundant. If a man by a blow upon his head have a portion of the skull driven in upon the brain, so as to press upon it considerably, all sensation and power of motion are suspended. His mental connection with the world around him is completely cut off. And not only so, but all mental action is arrested. The mind, thus shut in from the world around by the suspension of sensation, does not go on to act independently of the compressed brain. The man does not think; for if thinking did occur in such cases, there would occasionally be, as after dreaming, some recollection of what passed through the mind, after the pressure is taken off from the brain by the trephine and elevator of the surgeon. He lives, because the involuntary muscles, connected by their nerves with the top of the spinal marrow, (§ 229,) which is uninjured, carry on the breathing and the circulation. But though he lives, he is not now a moving, or a sentient, or a thinking being. His mind is as dormant as life is in a state of hibernation.

478. The same state of things occurs in apoplexy, and in the senseless state which accompanies most convulsions. And it may be remarked, that the degree of the suspension of the mental functions depends upon the degree of effect produced upon the brain. If, for example, in the case of injury, the pressure of the bone driven in upon the brain be not very great, the suspension will be partial; but if the pressure be considerable the suspension will be complete.

479. The dependence of the mind upon the brain is manifested in a great variety of diseases. The delirium of fever and of inflammation of the brain, and insanity resulting from chronic disease in this organ, show this absolute and inseparable connection of the mind with the material organization in our present state of being. We sometimes see the mind gradually blotted out by the progress of disease in the brain, so that a man of

even high mental powers becomes a drivelling idiot. So, too, a bad formation of the brain, or early disease of this organ often prevents mental development. Insanity is always the result of disease in the organization. This is so even when it is produced by moral causes acting directly upon the mind. The insanity in such a case is an *indirect* effect—the organization affected by the mind is thrown into a diseased state and reacts upon the mind, influencing its manifestations. "If the mind thus acted upon were a spirit, separated from the body, the result would be merely the feelings, which the motives applied would *naturally* produce, and not the unnatural feelings of insanity. It is not strictly proper then to speak of a 'mind diseased.' Let me not be understood to mean that mental derangement in every case is to be attributed to disease that leaves such palpable traces, that the dissecting knife would reveal it if death were to take place. There are diseased operations of the body, that are hidden from our view—so hidden, that they not only leave no traces, but often develop no characteristic bodily symptoms."* I shall recur to this subject of the dependence of the mind upon the brain in another part of this chapter, and shall endeavor to point out definitely what are the teachings of physiology, of our consciousness, and of revelation respectively in regard to it.

480. Observe for a moment the situation and the immediate connections of the brain, the organ of the mind. Its situation in the human structure is appropriately a commanding one. It is fitly placed at the summit of the structure, inclosed by that noble dome which I described to you in the Chapter on the Bones. And then observe that in its immediate neighborhood are the organs of four of the senses, sending their messages continually to the mind. Especially you notice that under the jutting arches of the front of the dome are the ever-moving eyes, looking out from their elevated place of observation; and at the sides of the base of the dome are the halls of audience, ever open and ready to transmit the messages that come to the soul through the vibrations of the air. And there, too, in the very front of this habitation of the mind is the face, indicating by the delicate, quickly changing play of its muscles the thoughts that are at work within. And lastly, there is the mouth, the outlet for the voice, the chief agent of the outward manifestations of the mind. Here then are clustered together in this

* "Physician and Patient," page 292.

small space, in the immediate neighborhood of the mind's habitation, its principal instruments of communication with the world around. When we are listening to eloquence, whether it be in the public assembly, or in the social circle, or in the more private intercourse of friendship, and observe, as the rich tones proceed from the mouth, the elevated and changeful expressions of the countenance, we are impressed with the idea, that, if it be the mind which constitutes the image of God in man, the face of man thus situated in the front of the mind's habitation, is the fitting outward emblem of that image.

481. It is interesting to observe how exceedingly rapid are the communications of the mind with the different parts of the body. Notice what the process is, or rather what the processes are, when you withdraw your hand from any thing that hurts it, as heat for example. An impression is produced upon the expanded nerve in the part—this impression is sent along the nervous tubuli to the brain—the mind there receives the impression—the mind in return communicates an impression to the brain—this impression goes by another set of nervous tubuli to the muscles—they act, and the hand is withdrawn. If it took as long to do all this as it has for me to describe it, the hand would be very thoroughly burned before it is drawn away. The same set of processes is gone through with, when in executing music, either with the voice or an instrument, a mistake is immediately heard and corrected. And so of other cases.

482. In the Chapter on the Muscles I spoke of the great variety in the motions of the body. In executing these motions the individual commonly knows nothing of the muscles with which he does it. Even the anatomist, who is familiar with the situation and arrangement of the muscles, seldom thinks of them while he works them in the production of different motions; and if he does think of them it affords him no assistance in their use. Great skill can be acquired in the use of the muscles, without any knowledge in the individual of the fact that he has such organs. In muscular action men commonly move a machinery of which they know nothing. They have only to will any particular motion, and the nerves are so arranged at one end with the muscular fibres that will do it, and with the brain at the other, that the message from the mind goes to exactly the right fibres, and the result is produced. For the infinite variations of motion in the body what complicated and intricate arrangements are needed! These variations, it is to

be remembered, do not result merely from combinations of movements, but are rendered vastly more extensive from the varying degrees of contraction in the muscles. If each muscle always acted just so much and no more, there would be even in that case great variety of motion, from its combination in various ways with other muscles. But the variety is made to be endless from the endless variation in the *degree* of their contraction. And for each one of these variations, both in degree and combination of action, there must be a different message sent from the mind along the nerves. In every motion the muscles that produce it must, so to speak, be told to act, and not only so, but they must be told just how far to act. In motions that are very compound, and at the same time exceedingly delicate in their variation, the accuracy and variety of the messages thus sent from the brain along the nerves are not only wonderful, but are beyond our conception. We realize this fully, when with the views above expressed in the mind, we watch a skillful balancer, as he executes his endlessly varied but exact movements. So, too, when we hear from Ole Bull's one violin such a mingling of sounds, that we feel that there must be a half a dozen violins played upon at once, how inconceivably rapid and numerous and complicated must be the messages that fly from his brain along the nerves to the muscles, and yet there is not a failure in one of them—not a fibre that does not contract at the right moment, and in the right degree!

483. The use which the mind makes of all the machinery of the senses and of the organs of locomotion does not come to it at the outset. It comes by training, and in some cases by very long training. The child at first uses its muscles bunglingly. It does not see or hear skillfully. It knows nothing at the first of the colors, or shapes, or distances of objects. It knows nothing of the direction or distance of sounds. It has all these things to learn. And for this purpose the organs of sense and the muscles are put into exercise at once, and the child begins its long process of learning on the day of its birth. Few have any conception of the amount of knowledge which is acquired in the first of the child's life. He is born not only with absolutely no knowledge of the world of things around him, but he has no skill in the use of the instruments, the muscles and the senses, by which he is to obtain his knowledge. These give him at first no very definite information; but by the constant exercise of them, and by comparisons between the reports of the different senses he soon adds rapidly to his stock of knowl-

edge, and becomes skillful in the use of his means of gathering it. But let us see a little more particularly how this is done.

484. I will speak first of the progress of the child in learning how to use his muscles. When he first puts them into action you see that he has no skill in using them. The action is aimless and awkward. You see in his movements none of that native grace of which so much is said. This is to be acquired, and all that is native about it is the power of acquiring it. He learns to execute very many motions before he comes to that complicated movement of so many muscles, creeping, and then the no less complicated but more difficult one of walking succeeds. How awkwardly he does this in his first attempts to preserve his balance, and how many failures must he encounter before he can perform this motion even decently well! The same thing can be said of learning to talk or to sing, for this is but a training of the muscles. It is thus gradually that all the voluntary muscles become educated. It is true even of the muscles of the face. At the first how expressionless ordinarily is the face of a child. You see nothing of those delicate movements of the muscles which in after years express every varying shade of thought and feeling. When he cries there is an awkward over action of the muscles, as represented in Fig. 183.

FIG. 183.

He learns to use these muscles partly at least, by imitation. His first lesson ordinarily is in smiling, which he soon learns by imitating the smile of his mother. But even this, simple

as it is, he does awkwardly at first, and he must go through a long process before he can master all the capabilities of expression in these little muscles.

485. Skill in the use of the muscles varies quite as much as any other acquirement in different individuals. It is wonderful in the juggler, the rope dancer, the skillful player on a musical instrument, and the accomplished singer. You will have some conception of what education can do for the muscles, if you contrast the awkward balancing of the child in walking with the agile and delicate balancings of the rope dancer, or the aimless and uncouth movements of the infant's hands with the rapid and varied execution of the player on an instrument, or the monotonous and coarse sounds uttered in a child's first attempts at singing with the varied melody of a skillful singer.

486. The senses are educated as well as the muscles. As you see an infant reaching out his little hands awkwardly with his unskilled muscles towards an object, it is manifest that he knows not at what distance the object is from him, and that he does not readily adjust his eyes to its distance, so as to see it clearly. He after a while by practice acquires the power of doing this. The same may be said of hearing. The little muscles which I described to you as so nicely adjusting the eye for seeing at different distances, and the ear for hearing various notes of sound, require training, just as the muscles do with which we walk or talk.

487. It is a singular fact that most other animals are born with so much more skill in the use of the muscles and the senses than man. While man is "in the nurse's arms," the chicken, for example, walks about as soon as it is hatched. He does it at first awkwardly, it is true, but he soon learns all that is to be learned about it. He is assisted materially, it is to be remarked, by the fact that his feet spread out over so large a space, that he has no hard lessons to learn in balancing as the child has. But this is evidently not all the difference. If it were, the child should be able to creep at the first, or even walk on its hands and feet, for in performing these motions there is no difficulty in supporting the centre of gravity. The same difference exists also in regard to the senses, for the chicken seems to understand distances at once. As it runs about to pick up its food it makes no mistakes on this score. But while man is thus at the first the most helpless of animals, in regard to both his muscles and his senses, by his process of learning he ultimately acquires vastly greater range and va-

riety of motion than other animals. And the same thing can be said of his acquirements through the senses.

488. The senses and the muscles are mutual teachers in this education which I have described. Thus, in singing, the accuracy of the sense of hearing in estimating sounds is acquired through the action of the muscles of the voice while the ear is listening. And on the other hand, skill in executing sounds is acquired by these muscles under the tuition of the ear. The dependence of the senses upon the muscles is not as absolute, however, as that of the muscles upon the senses. The ear can be trained in the accurate appreciation of sounds without any corresponding exercise of the muscles of the voice, though the two processes are ordinarily to a greater or less extent connected, and are corrective of each other. But even when the ear is trained without any aid from the muscles of the voice, the training is in some measure a training of muscles. For, as you saw in the Chapter on the Ear, § 415, there are certain little muscles that regulate the tension of the drum of the ear, which undoubtedly go through a process of training when we are learning to distinguish accurately between different notes of sound. While the dependence of the senses upon the muscles is thus a partial one, the dependence of the muscles upon the senses is, on the other hand, complete. Although the muscles have a sense of their own, a muscular sense, as Bell calls it, this is not adequate to be their sole guide in action, but it serves as a mere auxiliary in this respect. This absolute dependence of the muscles upon the senses is very strikingly shown in the fact, that the deaf and dumb are dumb simply because they are deaf. The voice in them has no teacher. The muscles which regulate the tension of the vocal ligaments, and those which articulate the voice do not act, because, as stated in the Chapter on the Voice, § 400, they have no guide in their action.

489. Although I have spoken of the education of the muscles and the senses, this language is not strictly correct. For the education is an education of the mind that operates through these muscles and senses. It is the training of the mind in the use of these instruments. This is very clearly shown in cases of idiocy. In these cases the defect in talking is proportioned to the mental deficiency. It arises from an incapacity on the part of the mind in using its instruments, the muscles and the apparatus of the senses, and not from any defect in the construction of these instruments. The larynx

and the articulating organs of the voice are perfectly well formed in the idiot, as I have stated that they are in the deaf mute. While, in the case of the deaf mute they are not used at all as vocal organs, because the mind, through the absence of hearing, has no power of regulating them; in the case of the idiot they are used to a limited extent, and in a very bungling manner, because the capability of regulating them is limited by the deficiency of the directing intellect. And what I have said of the muscles of the voice in the idiot is equally true of the muscles of the face. There is no defect of conformation, nor is there any lack of lustre in the eye, as is commonly supposed. The limited range of expression and its awkwardness arise from an incapability on the part of the mind of using the muscles of expression with facility and skill. The muscles have an incompetent teacher, and so learn to do but little, and do that little bunglingly; or, to speak more correctly, the deficient mind is not capable of learning to use them properly.

490. The education of the muscles does not extend to those which are involuntary. Though respiration, for example, is a very complicated act of many muscles, these muscles require no education to do their part skillfully. We have no need to superintend them, for their constant action is secured by an arrangement for nervous influence which is independent of the mind, as stated in the Chapter on the Nervous System. So, while the mind sleeps, or when it is locked up in the stupor of disease, these muscles continue to perform their duty, as well as when we are awake. The same substantially can be said of the muscles which perform the act of swallowing. Although this is a very compound, and, mechanically considered, a very difficult act, as shown in the Chapter on Digestion, § 78, it is performed as well in the first hour of the child's life as it is at any future period. The muscles that execute it need no training. And yet it is only after long and diligent training that the purely voluntary muscles, as for example those of the hand, execute movements which are no more complicated and difficult. The reason for this difference is obvious. The movements which are performed by the involuntary muscles, such as breathing and swallowing, are immediately essential to the preservation of life, and it is therefore necessary that they should be well executed from the first. Their perfect action is therefore secured by a nervous arrangement, which is independent of the mind. The voluntary muscles, on the other hand,

instead of being devoted, like the involuntary, to the maintenance of life, act as the instruments of the mind, and therefore the mind acquires the power of using them skillfully by dint of long-continued training.

491. In the education of the muscles, it is to be observed, that although during the process of learning the mind takes distinct cognizance at first of every movement, it after a while, as the education becomes complete, takes little or no notice of many of the movements, except when some error occurs, or some obstacle arises. Thus, when one is learning to sing or play a tune, the mind at first through the ear takes a definite and distinct notice of every sound, and makes a palpable exertion in every movement. But after the tune is learned, this ceases to be the case, and the movements seem to be associated together, in some measure independently of mental action. So in learning to walk the child notices each of his movements very distinctly. But when he has fully learned, but little thought seems to be expended upon the motions, except when some obstacle appears which interrupts their regular succession. When one walks in a reverie, the mind is most of the time wholly abstracted from the associated movements which make up the compound act of walking. In learning to read the child makes a distinct mental effort in regard to each letter, resorting to every aid which will help to make the effort a successful one, even to the putting the finger on each letter as he looks along the line. But as he becomes more and more skilled, the association of action of which I have spoken comes more and more into play. I will refer you to a partial explanation of the facts above alluded to, given in § 262, in the Chapter on the Nervous System.

492. It has been stated in § 325 and § 476 that the mind receives impressions only through the senses, and imparts them only through the muscles. These act as the instruments of the nervous system, the senses being the *inlets* and the muscles the *outlets* of communication. And it has been generally considered as a settled point, that these are the sole channels through which the interchange of thought and feeling is effected in our present state of being. But it has been pretended that other mysterious modes of communication have in these latter days of progress been discovered. The phenomena presented by *animal magnetism*, as it is called, are claimed by some to demonstrate, that there is in some cases a peculiar means of communication, distinct from those which are usually

employed. It has been fancied that something analogous to magnetism is the medium of connection in such cases, and hence the name of animal magnetism. Through this medium, it is asserted, that thoughts and sensations pass from one person to another, independent for the most part at least, of the ordinary conditions on which communication depends. The phenomena have been presented at different times under different phases, and the theory framed to account for them varies somewhat from time to time, according to the varying character of the phenomena, and the tastes and imaginations of the believers in this so called science. Amid all the various forms which it has thus assumed, with its corresponding diversity of names, one thing has always been true of it, viz., that whenever any efficient tests have been applied, it is shown to be a large superstructure of falsities built upon a very few facts. And in view of the uniform results of these tests, we may confidently say, that as yet there has been no satisfactory proof, that there are any other channels of mental communication, than the ordinary ones furnished by the senses and the muscles. Most minds are bewildered by the strange, and sometimes inexplicable things, which appear in the exhibitions which they witness, and are ready to adopt any plausible explanation which may be offered. But some simple yet searching tests have thus far, whenever applied, always sufficed to expose the delusion.

493. In illustration of the manner in which these tests demolish the lofty pretensions of this so called science, I will give a single example. The exhibitor asserted that whatever was in his mind, realized distinctly and vividly, had its image in the mind of the subject whom he magnetized, by means of the peculiar connection thus established between them. Any decided sensation, therefore, which he felt, the subject felt also; and if he fixed his thoughts upon any thing, the subject thought of the same thing. I observed that whatever was said by the subject, in relation to any sensations or thoughts in the operator, was generally in reply to questions on the part of the operator himself. And as these questions were sometimes repeated in various forms before correct answers could be obtained, I suspected that the information requisite for the answers was communicated to the subject in this way. I, therefore, proposed to the exhibitor to try some experiments *without questions*, as these, according to his theory, were clearly not necessary; for, if there were such a channel of communication

between his mind and that of his subject as he asserted, the aid of the voice was not required. The proposition was manifestly so fair an one that he could not refuse to comply with it. But his experiments performed in this way failed altogether, and the audience, caring less for a strict search for truth than for the continuance of their amusement, showed little relish for the interruption, and the pseudo-scientific exhibition went on. I applied other tests as I had opportunity, which developed the evidence of imposture here and there in the exhibition, and though many sober and intelligent citizens were deluded with the belief that they had enjoyed a rational and truly scientific amusement, I had no doubt that the whole was a piece of jugglery. There was one feature in the exhibition, which of itself was enough to condemn it as a ridiculous imposture. The operator claimed to have a sort of absolute control over the subject, so that at will he could hold him in a connection with himself so insulated that no impressions could be imparted to him by any other person, and yet could dissolve this connection and put him into connection with some one else, with as much facility as a locomotive can be switched off from one track on to another. And ridiculous as this shifting of mental connections is, this was quite as successful with the audience as any part of the exhibition.

494. Some of the phenomena presented in the exhibitions of animal magnetism afford interesting illustrations of the influence exerted upon the body through the mind. The mental influence, exerted by the operator upon his subject, often causes a condition of the nervous system, which is analogous to somnambulism, or to some of the forms of hysteria. The manipulations practiced, the looking the subject intently in the eye, the holding of a piece of metal in the hand with the eye fixed upon it, and other expedients, help to produce the impression in the mind of the subject, that a mysterious and resistless influence is coming from the operator upon him, and is stealing over his system. It is not strange that this should occasion such physical results as we often see, when the mind and the nerves are very susceptible. This is the simple explanation of all that is positive in what such exhibitions present to us. There is no such thing as a magnetic influence, and animal magnetism is a misnomer.

495. The state of nervous system often produced is not inconsistent with imposture any more than hysteria is. As in the nervous states exhibited by this disease there is often a strange

perversion of the moral mingled with that of the physical, so there is also in the state produced by the mental influence of the magnetizer. Accordingly his most available subjects are women found here and there in every community, who, through this mingled moral and physical perversion, have acquired a permanently morbid state of mind, that makes them like to be thus petted, and to be the wonder of a gaping multitude. There is often in the exhibitions of animal magnetism self-imposition at the same time that there is imposition upon others. In the case of travelling exhibitors there has always been collusion enough to stamp the character of jugglery upon the exhibition. And in other cases, where both the operator and the subject are honest, there is delusion in both, and they impose not only upon themselves, but upon each other, as well as upon those that witness the performance.

496. One of the peculiarities of the state of somnambulism which is induced by the magnetizer, is the ready obedience of the mind of the subject to *suggestive* influences. It is alive to any suggestions which come from the mind to which it supposes itself bound by a magnetic spell, and is often in fact shut up to influences from that source alone, so as to be insensible to influences from any other quarter. The somnambule is possessed with one idea, and that an all-absorbing one, because invested with such mystery. His insensibility to all that is not in accordance with this idea is to be accounted for in the same way that we account for the fact, that a wound received in battle is often unfelt till the excitement of the battle is over, and other similar facts, as alluded to in § 226. This state is often quite successfully imitated by impostors; and sometimes there is a mixture of a partial real somnambulism with imposture, similar to that which occurs in the case of the hysterical condition. Of course when this mental connection is so easily shifted from the operator to bystanders as was described in § 493, there must be sheer imposture. Whether there be full somnambulism alone, or this in a partial degree and mingled with deception, the influence of the principle of suggestion is very apparent. Nothing can be done without questions. Leading questions suggest ideas to the mind of the subject, and an audience led on by love of the marvellous and the exciting, are readily satisfied by the coincidences that occur in the exhibition, while the failures are disregarded and forgotten.

497. In the state of somnambulism induced artificially by the so-called magnetizer, as well as in that which occurs from

other causes, there is often an exaltation of the powers of the senses. Thus, sometimes a somnambule can read through envelopes of even many thicknesses, from an exaltation of the sense of vision.* But all pretensions to reading through bodies that have no pores or interstices, as metallic substances, or to reading from other parts of the body, as the pit of the stomach, or the back of the head, are impostures. So too are all the pretensions to seeing what is going on in other places, or inside of the body. This clairvoyance, as it is called, has precisely the same claim upon our confidence that fortune telling has, and no more. Real searching tests have always sufficed to expose its imposture.

498. I have introduced the above views of what is generally called animal magnetism, in order that you may be prepared to apply the proper tests, whenever such popular delusions claim your confidence. I have introduced them, also, because, whatever real phenomena do appear in the exhibitions presented to us under this name, afford some interesting illustrations of the influence of the mind upon the body. They add another chapter to our view of the mysterious connection of the physical with the spiritual, secured by means of that wonderful apparatus, the nervous system. It is from this consideration merely that they claim the attention of the physiologist. The so-called animal magnetism, when thoroughly sifted is dissipated, and there are left as a residuum only a few phenomena, which offer nothing particularly new, but are chiefly interesting from their analogy to phenomena with which we were already familiar. And its boast of the discovery of a new medium of mental communication is, as you have seen, entirely groundless.

499. In the Chapter on the Nervous System I spoke of the different offices of the different central organs of this system. The brain, as you have seen, is more especially connected with the mind, and is the great instrument through which mental

* Many of the statements, however, of such cases, could have been found to be false if the proper tests had been applied. The failure in testing, so common in these cases, I will exemplify by a single case, which made some noise in its time. It is a case reported by Col. Stone in his famous pamphlet. He gave the clairvoyant a sealed packet with a very odd sentence in it, which she read, as the Colonel supposed, without opening it. But how did he know that she did not open the packet? Simply because she returned it to him a day or two after apparently in the same state as he gave it to her, accompanied with a copy of the sentence contained in it. This he considered good proof, but it is defective in its most essential point. If she could read the packet without opening it, why did she not do it in his presence? There is not a particle of evidence that any one saw her do it. The true test was an easy one, but it was not applied. There is such a thing as skill in opening seals and replacing them so as to avoid detection, and until we have proof that this was not done we are not called upon to believe that the clairvoyant read through the envelopes.

manifestations are made. But it is only a certain part of the brain, the *cerebrum*, *a*, Fig. 72, that has this special connection with the mind. The *cerebellum*, *b*, Fig. 72, it is supposed, is especially devoted to the motions of the body, for it is found in animals that it is developed in proportion to the range and variety of motion. From extended observations on this point in comparative anatomy there seems to be good reason to conclude, that the cerebellum is the great central apparatus for *combining* the various compound motions of the body. It is uniformly found to be larger in those animals that have great complication in their muscular movements, than in those in which these movements are of a simple character. Thus, in animals whose most complicated motion is walking, as the hoofed quadrupeds, the cerebellum is much smaller, than in those animals that climb and that take hold of things with their paws. In man it is much larger than in any other animal, for he walks erect, and thus brings into action a very large number of muscles in this delicate balancing movement (for such it is), and then, in the individual parts of the body, especially the hand, he executes a great range of very complicated movements. It is more developed in monkeys and apes than in any other of the inferior animals, because, with their capability of extensive variety of posture, and their power of seizing objects with their extremities, they obviously come nearer to man than any other animal in the varied combination of their muscular action.

500. The conclusions, thus arrived at by comparative observations in animals have been confirmed by experiments. It has been found by physiologists, that if the cerebellum be removed in an animal, with as little disturbance as possible to other parts, although the sensibilities remain, and motions are performed, the power of combining muscular actions in definite compound movements, such as flying, walking, &c., is lost.

501. These conclusions have also been to some extent confirmed by observation of the phenomena of disease. The testimony from this source, however, has not as yet been very decided for two reasons. First, because disease in the brain is not apt to be confined to one portion of the organ. And secondly and chiefly, because we have not had a sufficient number of observations of cases on this point. It has been observed, however, in some interesting cases of chronic disease in the cerebellum, that deficiency in the performance of the compound movements of the body was a prominent symptom. An *unsteadiness of gait* was remarked in these cases. The *negative* testimony which

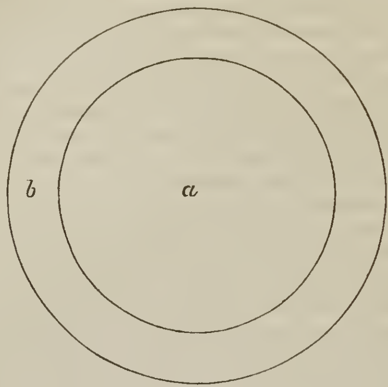
disease gives us in regard to the office of the cerebellum is very conclusive. The mental phenomena of disease, when it is fastened upon this particular portion of the brain, show that this is not that part of the organ where the thinking is done.

502. It is chiefly, as you see, by observing the different developments of the nervous system in various animals, in connection with the different functions performed by this system, that we can discover the uses of its different parts. In pursuing observations of the animal kingdom in this way, we find a more and more complicated nervous apparatus, as we proceed from the lower animals up to man. We find part after part added, and with every addition of a part we find new functions. And as we study any particular part in relation to the functions which appear as connected with it, we see that these functions are prominent in proportion to the amount of the development of the part. Thus, as before stated, we find the size of the cerebellum is in proportion to the variety and complication of motion in the animal, while that of the cerebrum is in proportion to the amount of intelligence. And in relation to the cerebrum itself we find that the amount of intelligence depends on the amount of its gray portion, the vesicular substance. In man, therefore, this part of the cerebrum is very much greater than it is in any other animal. It is the difference in the amount of the gray substance which constitutes the grand distinction between the brain of man, and that of any of the higher orders of animals, for in all other respects his brain differs very little from theirs.

503. In looking at representations of the brain, as in Fig. 74, it would seem at first view that the gray substance, the working part of the cerebrum, is much less in amount than the white portion, which serves only for transmission. But this is not so. The eye is deceived, because the white substance is all together in one central mass, while the gray substance is spread out in an external layer. This is very plainly illustrated by Fig. 184. Here the area, *a*, contained in the inner circle, strikes the eye as being larger than the area, *b*, included between the two circles, and yet these areas are precisely equal.

504. Observe for a moment in this connection the concurrent evidence, by which we determine what the function of the gray substance of the brain is. It comes from two sources. The first is that which is furnished to us by the structure of the cerebrum. As stated in § 206 and § 232, the gray portion is made up of cells, while the white portion is composed of tubuli.

FIG. 184.



These tubuli are such as we find in the nerves, and in fact are continuous with them. We very properly infer, therefore, that as the nerves serve only for transmission, the white part of the brain does the same. Is has, therefore, nothing to do with the thinking, and yet this we know from other facts, (§ 477 and 499,) is done in some part of the cerebrum. So we infer necessarily that it must be done in the gray substance. And here, to confirm the truth of this inference, comes in one other source of evidence, viz., the comparison between different animals in regard to the correspondence between the amount of the gray substance and the amount of intelligence. This I remarked upon in § 502, and need not dwell upon it farther.

505. This dependence of the mental faculties upon the gray substance, the outer part of the brain, seems to give some countenance to the doctrine of phrenology. But there is no evidence from an examination of this substance that it is arranged at all in separate organs, as instruments or seats of different faculties. And all the facts which have been collected in regard to the external conformation, as indicating the comparative prominence of different organs with their faculties, go to show, when properly examined, that the mapping out of the brain which phrenology does so definitely is altogether a fiction. The question in regard to this is wholly a question of evidence. For although we can see no division of the cortical substance into organs, yet

if the pretensions of phrenology in regard to the results of the external examination of heads are well founded, we must acknowledge such divisions to exist, though even the microscope cannot reveal to us their boundaries.

506. It would lead me into too long a discussion to examine fully the evidence in regard to these pretensions of phrenology. Besides stating the general fact, that the failures in describing mental and moral character from external examinations of the head are such, when the examination is conducted fairly, as to exhibit the falsity of these pretensions, I will only allude to one or two particular facts, and dismiss the subject. In the phrenological map of the cranium there are located some half a dozen organs along in the region of the eyebrows. Now, you will remember that the frontal sinus extends along in this locality. This sinus varies very much in size in different individuals. It is obvious, therefore, that an external examination can give us no accurate idea of the quantity of brain in that locality. Take another point. Phrenologists have always insisted that there was the most positive evidence, from examinations of the head in man and in animals, that certain faculties or propensities have their organs in the locality where the cerebellum lies. But all this mass of vaunted evidence is swept away by the discovery stated in § 499, that the cerebellum is chiefly concerned in effecting the compound motions of the body. I might go on to examine in this way the rest of the evidence adduced in favor of the truth of phrenology, and show that there is no satisfactory evidence of the correct localization of any one of the organs paraded with such definiteness on the cranial map of this so called science. But it would occupy too much space.

507. The only fact which seems to give any countenance to phrenology is that general fact, which is matter of common observation, that the front and upper portion of the brain—that which occupies the forehead—is commonly developed in proportion to the development of the intellect. This would seem to show that the intellectual faculties have their seat in this part of the brain. But it is far from *proving* this to be so. For it may be, that a general enlargement of the cerebrum is for some reason accommodated by having the forehead enlarged, in preference to other portions of the cranium. For it is evident that a brain which is larger alike in all its parts than usual, can, as it is a soft yielding organ, be equally well accommodated, whether the cranium be made of unusual size in only one direc-

tion, or in all directions. The fact that in the child the forehead is more prominent than in the adult, is inconsistent with the supposition that the intellect has its seat especially in the front part of the brain, for the child has more of the instinctive and less of the intellectual than the adult. I may remark in this connection, that the phenomena presented by injuries and by disease in this part of the cerebrum, have not, as thus far observed, seemed to show that it is the peculiar seat of the intellectual faculties.

508. The size of the anterior portion of the brain, above referred to, may be estimated by the measurement of the *facial angle*, so termed, proposed by Camper, a Dutch naturalist. This angle is formed by drawing two lines as represented in Figures 185 and 186. The line, *a*, *b*, is drawn from the most

FIG. 185.

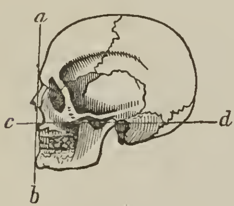
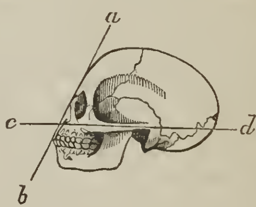


FIG. 186.



prominent part of the forehead to the front of the upper jaw. The line, *c*, *d*, is intended to represent the line of the base of the brain, and runs from the orifice of the ear along on the floor of the cavity of the nose. It is manifest that the less prominent is the forehead, that is, the less brain there is in the front part of the head, the more acute will the angle be that is formed by these lines. In Fig 186, which represents the skull of a negro, this angle is more acute than in the skull of the European, Fig. 185. In animals this facial angle is much more acute than in man. In the monkey tribe it varies from 65° to 30°, while in man its average is about 75°. The ancient Greeks, wishing to give the aspect of great intellectual superiority to their statues of deities and heroes, made it in them as high as 90°.

509. It is proper to remark here, that while it is clear that, as a general rule, the amount of intelligence is to some extent proportioned to the amount of the cerebrum, both in man and in animals, the rule is not an invariable one. Size is far from

being the only measure of power in this case. What differences there may be in intimate structure, to compare with the mental differences, we know not. Even where the rule stated above holds good, the difference in mere bulk is far from being proportionate to the mental difference. The mind of a Newton or a Shakspeare is gigantic compared with any common mind, but the brain in such cases is not very much larger than ordinary brains.

510. In relation to the evidence drawn from a comparison between different animals, in regard to the functions of the nervous system, there is one significant fact which must not pass unnoticed. Though, as we rise in the scale of animal life in our observations, we find every new addition of functions coupled with some new additions of structure, until we come to the higher animals, *we do not find this to be so when we pass from them to man.* The brain, it is true, is larger in man than it is in them, and has much more of the gray substance; but there are no *essential* differences of structure in his brain, to correspond with the added mental qualities which so decidedly distinguish him from the brutes. These qualities constitute something more than a difference of *degree.* It is a difference of *kind.* And, therefore, it is a great and a significant fact, that there is no corresponding difference of kind in the organization of the brain.

511. The qualities to which I refer I have alluded to in the first part of this book (§ 40). They are possessed by every human being to some extent, however debased he may be; and, on the other hand, they are never possessed by any of the inferior animals, however high their mental manifestations may be, and however much they may be improved by training. Though there be so wide a distance between such minds as Newton, and Milton, and Shakspeare, and the lowest representative of our race, yet in him are contained the elements of the excellence to which they arrived. But no one dare assert this to be true of the very wisest of the inferior animals.

512. The distinction between man and animals is a definite one. It is as definite as it would be if it were based upon difference of organization. The barrier is fixed; and not a step over it has any animal advanced, with all the training which may have been expended upon him. No animal, however intimate has his intercourse been with man, has ever acquired man's habit of abstract reasoning, or manifested any real knowledge of the difference between right and wrong. Prof. Guyot does

not speak too strongly when he says, "I will even go farther than is ordinarily done, and I will say, that there is an impassable chasm between the mineral and the plant, between the plant and the animal; *an impassable chasm between the animal and man.*" Surely if the impassable chasm between minerals and vegetables, and that between vegetables and animals, are worthy of note when we take a comprehensive view of the material world, so also is that which is much more manifest as existing between animals and man. When, therefore, the comparative physiologist, in his examination of mental manifestations in connection with physical developments finds, as he comes to man, that in him are peculiar and distinctive mental manifestations with no corresponding physical developments, he should deem it to be an important fact in science, which should not be slurred over, or passed unnoticed, as is often the case. I shall allude to certain bearings of this fact in another part of this chapter.

513. In looking at the facts presented in this chapter and in that upon the Nervous System, you must have been continually struck with the intimacy of the union between the mind and the body. On this subject I thus remark in another work. "There are various figures used to illustrate this connection. The most common one is that in which the mind is spoken of as dwelling in the body as a habitation. In a certain sense this is true. This tabernacle of flesh, as the Bible aptly terms it, is in its present state a habitation, which the mind is to leave in a short time, to return to it, however, at length, rebuilt and refitted in a more glorious, an incorruptible form, to dwell in it then forever. But this illustration of the mysterious connection of the mind with the body is but a *partial* one—it does not express the extent nor the intimacy of that connection. The mind is not a mere dweller put into this habitation. Its union with it is not thus loose and easily severed. It is bound to its every nerve and fibre, so that the least touch of the body at any point affects the mind. Instead of being put into the body, it has, being thus interlaced, as we may say, fibre with fibre, grown with its growth and strengthened with its strength. In the feebleness of infancy the mind is just as feeble as the body, and they both grow together up to the vigor and firmness of manhood, and both decline together in old age. So close is their union through all the stages of life, and so equally is each affected by the joys and sufferings of the other, that we might justly conclude that at death, when the tabernacle crumbles into dust, the mind falls with it never to rise again, had not a

divine revelation told us that, indissoluble as this connection appears during life. Almighty power will dissever it, and release the soul from the thousand ties that bind it to its habitation, at the very moment of its destruction. Were it not for this assurance of our immortality, we could look forward in the uncertain future to nothing but blank, drear annihilation, as awaiting our minds, just as it does the minds of the brutes that perish.

514. In our carefulness to avoid materialism, we are too apt to look upon the mind and the body as two separate and independent things. At death they do indeed become so, but who of us knows that they would, were it not for the *fiat* of the Almighty? Who knows that there is not a necessity for the putting forth of his power in each individual case at the time of death, to prevent the mind of man from dying with his body, just as the mind of the brute does with his? The very prevalent notion that the mind is *essentially* indestructible, and that it is put into the body as a separate thing, having the power *of itself* to leave the body whenever it dies, rests on no substantial proof. That it is *destined* thus to leave the body is quite another thing."*

515. The nature of the connection of the mind and the body is a great mystery. Still, there are many things which we can know in relation to it. The sources of our knowledge on this subject are three, viz., the investigations of *Physiology*, the testimony of *Consciousness*, and that of *Revelation*. Each of these kinds of evidence throws light upon the others. If, therefore, we use all of them, giving to each its due limits and force, we shall come to some certain and valuable conclusions. But if we take any one of them alone, we shall be liable to be led into gross error.

516. There is in some physiologists a disposition to rely upon physiology alone, to the exclusion of the other sources of evidence, in the investigation of this subject. In doing this they are driven to this alternative. Either they must be content with a very limited knowledge of the subject, or they must rely upon mere presumptive evidence for many of their conclusions. And commonly the latter is the course which they pursue. They are not content with the very limited conclusions to which they are shut up by the absolute proof furnished by physiology. They boldly reason, therefore, upon what they deem to be

* "Physician and Patient," from the Chapter entitled "The Mutual Influence of the Mind and Body in Disease."

probable. And they are invariably led into error. This I propose now to show.

517. In order to get definite ideas of the manner in which the erroneous conclusions are arrived at, let us view matter in its various states and connections. Unorganized dead matter you see to be entirely different in some important respects from living organized matter. The distinction is a definite one. It is easily recognized, and none but dreamers in science have failed to see it. Though Robinet and others of his class have sought to obliterate it, in carrying out their fanciful notions, (§ 48,) and though some have supposed that there was a *latent* life in all unorganized matter, ready to be called into action on the application of the appropriate excitants, it is considered by all rational observers as a settled point, that there is an essential distinction between common dead matter and living matter. The latter is endowed with certain properties that the former has not. They are termed vital properties. They control to a certain extent the mechanical and chemical properties which both forms of matter have in common. Some suppose that what we call life is a single principle; but others suppose the endowment to be compound, made up of different principles or properties. But this question we need not discuss. All that concerns the view I am presenting is the mere fact of the endowment.

518. Let us go a step farther. Some living beings have more endowments than others. All have those of *organic life* in common (§ 32). But there is an *animal life* also, which by means of the nervous system is superadded to the organic. And, as we trace the animal kingdom from the lowest animal up to man, we find the endowments connected with this system multiplied as we advance, till in him they are more complicated and extensive than in any other animal. This is especially true of intellectual endowments, those which are merely instinctive being more developed in many, perhaps we may say most, of the inferior animals. And in man we find special mental endowments, of which other animals present not the faintest trace.

519. Now the question arises, whether intelligence is like life, a mere endowment of matter, or whether it is in some measure independent of it. In other words, whether it is a principle or set of principles with which matter is endowed, or an immaterial something which acts through matter as its instrument. How much does bare physiology teach us on this

question? It has often been claimed that it can teach us much, and the most bold conclusions have sometimes been ventured from this quarter. But mere speculation has in all such cases been deemed to be proof. Physiology does show us, as I have before said, that the spiritual is in this world always connected with the material, and that mind never acts independently of the matter with which it is connected in the brain. But it gives us no light upon the *nature* of this connection. It is well for us to know how deficient are its teachings on this point. For all that it can teach us, we know not but that the mind may be a mere result of action in matter. It neither tells us that it is so, or that it is not. It leaves us entirely in the dark on this point. Indeed so far as it affords presumptive evidence, it appears to teach, that mental phenomena are results of matter, acting in consequence of certain endowments or tendencies imparted to it, just as secretion is in living substances, or chemical action in those which are not living. Accordingly those who have relied upon physiology alone on this subject, have adopted various forms of materialism. Some have supposed that thought is a mere product of matter, and that the brain secretes it as the liver secretes bile. Others have taught that the mind is "a bundle of instincts," each residing in some particular part of the brain as its organ. This has been the doctrine of some prominent phrenologists.

520. Let us look at living matter in another point of view, and see to what physiology alone, if at all venturesome in drawing conclusions, will lead us. Let us look at the origin and growth of the thinking animal. Take, for example, an animal the formation of which we traced in the Chapter on Cell-Life, § 210. The beginning of the bird as it forms in the egg is a simple cell filled with a fluid. This produces other cells, and soon the organs and the limbs of the animal are formed. At length the animal bursts the shell, and comes out not only a living and sentient being, but a thinking being. It has a mind which feels desires and emotions, and prompts the muscles to action to effect its purposes. Organization here precedes the development of mind so far as we can see, and therefore it would seem that mind is a result of organization. Especially does this appear to be so, when we find that the amount of mind in different animals is proportioned to the amount of a certain part of the organization, the brain. All this is as true of man as it is of other animals. And besides, we see in man that as the organization becomes perfected, the intelligence is proportiona-

bly increased. In infancy, when the organization of the brain is imperfect, the intelligence is small in amount, and grows with the growth, and strengthens with the strength of the brain. And as the mind thus grows with the body, it appears to perish with the dissolution of the organization, and in the case of the inferior animals undoubtedly does so.

521. But it may be said, that the physiologist observes that the mind designs, and devises means to carry out its designs, and this shows that there is an immaterial principle that moves the machinery of the material organization. This is a plausible view of the subject, but it is only plausible. Physiology alone cannot prove it to be a correct view. For, if we limit ourselves to her teachings alone, it can be made to appear by the same line of argument, that mind is at work in all the phenomena that we see in living beings. In the formation of any part, as you saw in § 163, in the Chapter on Formation and Repair, the formative vessels work after a fixed plan, and coöperate together to accomplish the object. They seem to act intelligently, as if they had a mind by which they designed, and devised means for carrying out their designs. And the formative and other vessels thus act together, proportioning means accurately to ends, not only under fixed and regular circumstances, but they do so under varying circumstances, to meet exigencies. Thus, when an artery supplying a limb is tied, § 169, the formative vessels enlarge the arteries in the neighborhood, in order that the blood may be supplied to the limb in suitable quantity. That is, they construct after a larger pattern to meet the new want, just as if they were informed of it and acted accordingly. Take another example afforded by the formation and discharge of an abscess, as described in § 170. In this case, as the abscess forms, various operations are going on, with different sets of vessels coöperating together to effect a common purpose. And when the abscess has made its way to the surface, and discharged itself at an outlet, a change comes over the operations, in order to restore the part to its usual state. The different vessels accommodate themselves to this change, as if they were intelligent workmen, acting in conformity to a design or plan of their own, upon which they had agreed. Other examples might be cited, both from vegetable and animal life, all showing design and coöperation in effecting purposes.

522. In such phenomena we see a striking analogy to those of instinct, and even to those of intelligence also. It is this analogy which has led some in their speculations to adopt the

idea that life and soul are the same thing. Hence, too, many phenomena in vegetable life are in common language often called instinctive. Thus, it is said, that when a seed sprouts, the roots instinctively seek the ground, and the stalk and branches instinctively seek the air and the light. This is even the case sometimes when the seed is placed at some little distance from the ground. So, too, if a plant that naturally grows in wet ground is put into dry soil, but in the neighborhood of a wet spot, it shoots forth roots abundantly towards this spot, rather than on the other side.

523. But the evidence from physiology does not all tend to materialism. There is some negative evidence which has a different bearing. I refer to the fact stated in § 510, viz., that, while man differs in his spiritual nature so widely and so specifically from the inferior animals, his brain exhibits no corresponding specific difference in structure, but only a difference in amount. The difference in degrees of intelligence in the animals below man is marked by a corresponding difference in the amounts of the gray substance. And if it were true that man, as some think, differed from them only in having a higher degree of intelligence, we should expect to find in him a mere increase of this substance. But as his mind differs from theirs not merely in degree, but in kind also, we should have reason to expect, if mind were wholly dependent on organization, that the anatomist would find not only an increase in the quantity of the gray substance, but also a difference in its structure.

524. But strong as this evidence is, it appears to be strongly rebutted, perhaps almost overborne, by the other evidence which I have cited from physiology. And the physiologist might perhaps say that, although as yet no difference of structure has been found that corresponds with the mental difference, future investigations with the microscope may discover some subtle difference of structure which now escapes our notice. But this it must be allowed is not at all probable. On the whole it may be remarked, that the fact of which I have been speaking, although significant and valuable as being coincident with evidence drawn from the other sources, yet considered simply in connection with the physiological evidence, the evidence from the other sources being wholly shut out, it is doubtful how much weight it ought to have. The physiological evidence, taken by itself is conflicting, and looking at the whole scope of it, the preponderance must be acknowledged to be towards materialism.

525. It is quite clear then, that the physiologist cannot well

avoid materialism, if, in examining the connection between the mind and the body, he rejects all evidence beside that which physiology furnishes. He can be saved from this result only by being content with the narrow limits, to which he is shut up, if he confine himself to *absolute* proof. As we have already seen, the positive knowledge that physiology gives us on this subject is exceedingly narrow. We soon come to the line that divides between the known and the supposed. And if we attempt to go beyond that, our conclusions as to what is probable will quite certainly lead us to the result which I have pointed out. The need, therefore, of the evidence drawn from the other sources that I have mentioned is most palpable. The physiologist must confess himself to be under the necessity of going out of his physiology, in order to learn all that can be learned upon this subject. At the best, there is much mystery in relation to it which we cannot penetrate, with all the light that we can bring to bear upon it. And the mystery is deep indeed, when we call to our aid only the dim light of physiology. It needs some other light to deliver us from the confusion of ideas, into which we are introduced by the analogy existing between the phenomena of life and instinct and intelligence, in relation to their connection with the organization of matter. Let us look then at the evidence which comes from the other two sources, viz., our consciousness, and revelation.

526. Every individual is conscious that, as he feels and thinks and acts, he, that is his mind or spirit, acts upon the structure of his body, and is acted upon by it. It is not a consciousness that he as a *material body* does all this. He feels that it is a power within that does it, and he instinctively separates in his ideas the power from the different parts of the body, and from the body as a whole. He is conscious too of a responsibility in relation to the thoughts and acts of the spirit within. He has a knowledge of right and wrong, and has self-reproach on doing wrong, and self-approbation on doing right. It is this consciousness of a self-acting immaterial spirit in this material body, that constitutes the basis of all character, and of all the moral relations of man to his fellow man, and to his Maker. Every body acts upon the testimony of this consciousness as being valid and certain testimony. And, however the physiologist may reason about matter and mind, as if the latter were a mere product or endowment of the former, yet as a man, as a member of society, as a subject of government and law, he cannot avoid acting upon the ground, that mind in a certain sense controls matter,

and is responsible for its acts independently of the matter with which it is connected.

527. Now the evidence which this consciousness affords us should suffice to keep us from the materialism, into which physiology taken alone would be apt to lead us. It shows us that, although the mind is developed with the material organization, and can act only with it, it is not its mere product, nor one of its endowments. It shows us, on the other hand, that it is in some measure independent of matter, and that its dependence upon it is only a dependence of connection, matter being the instrument of mind, through which it acts on external things, and is acted upon by them. The evidence from this source is of a positive character. We are driven by it to the alternative, of believing that the mind is an immaterial, self-acting agent, in some measure independent of matter, or of harboring the impious and monstrous belief, that the Creator has implanted in the bosom of man a lie, and that he is living a horrible farce, acting in view of moral relations and responsibilities that have no existence.

528. This positive testimony of our consciousness is confirmed by the testimony of revelation. This is not done by any formal array of proof. The existence of the spiritual part of man as a self-acting responsible agent is assumed as a fact that needs no proof. All the statements, and teachings, and appeals of the Bible recognize it as a fact known to the consciousness of every man. The Bible, therefore, may be considered as simply affirming that the testimony of our consciousness on this point is valid testimony. But the Bible goes farther than this. It gives us one great fact of which neither physiology nor our consciousness could assure us. I refer to the mind's immortality. Our consciousness could, it is true, give us presumptive evidence to show that the soul with its high powers and aspirations is to live after the death of the body. But it could furnish us no absolute proof of the fact. And its presumptive evidence would be effectually rebutted by the presumptive evidence from physiology, which, as you have seen, points in another direction. We are so familiar with the mind's immortality as a known fact, and we so uniformly think of it in connection with the death of the body, that we are not aware how absolutely dependent we are upon revelation for all that we know in relation to it. If there were no revelation, and death were to us an unknown event, and we were now for the first time called upon to witness the death of a friend, how little should we know, and how con-

fused would be our thoughts in relation to the great mystery before us! "What is it?" we should ask. "Is it sleep?" No. We never saw any one sleep thus. What is it? Who can tell us?" And we should wonderingly watch to see some signs of awakening, not giving up all hope till decay begins its ravages on the loved form before us. Then, as we should from the dictate of nature, consign to the earth the friend who was so recently among us a breathing, moving, speaking man, now a mere mass of decaying matter, we should feel that we bury there not the body only, but all that belonged to that body during life—the whole man. Thought and feeling, as well as life and motion, would appear to us, untaught of God, to be extinguished in the grave. Even if some one should utter all tremblingly the hope, that there might be a subtle spiritual part of our friend, that would some time in some form return again to our society, that hope would at once be crushed by the reflection that whatever it was in our friend that thought and felt, it came into existence with the body, was infantile when the body was, grew with the growth of the body, and strengthened with its strength, and therefore now, so far as we can see, has perished with it. Nature utters no voice to tell us otherwise. She emits no light to illumine the grave. Darkness and silence rest there, till the light of revelation shines upon it, and God proclaims man's immortality.

529. I have thus spoken of the three sources of evidence in regard to the connection of the mind and the body, and have indicated the character of the evidence furnished by each. I have shown particularly that if the attention be confined to that which is furnished by physiology, the mind is apt to be led into materialism. But the attention should not thus be confined. All the three kinds of evidence should be employed and should be brought to bear upon each other. If this be done, the discrepancies in the evidence from physiology are cleared up by the evidence afforded by consciousness and revelation, and we see the true value and bearing of the fact, that the specific mental difference between man and animals is not attended with a corresponding structural difference. Though this fact operates merely as conflicting evidence, when taken simply in connection with the rest of the facts developed by physiology; when, we come on the other hand, to take the whole range of evidence from the three sources spoken of, it is exceedingly satisfactory as concurring with the testimony of consciousness and revelation. At the same time, those physiological phenomena, which taken

by themselves seem to show so strongly that the mind is wholly dependent upon organization, are so interpreted by the evidence from the other sources, that the dependence is seen to be for the most part a dependence of connection only, the brain being the instrument of the mind.

530. The evidence from consciousness and revelation is of the most positive character, and cannot be set aside by evidence from any other source. Other evidence may serve to interpret it, but cannot nullify it. The attempt is sometimes made to set it aside by urging the presumptive evidence of physiology, as if it were absolute proof. But most physiologists engage in no such futile and unchristian efforts, but give due weight to the testimony of consciousness and revelation in all their investigations of the mysterious connection of the mind and the body. The influence of Carpenter, an English physiologist, whose works are more extensively used by students than those of any other physiologist, is especially to be commended in this respect. And although skepticism occasionally utters its plausible falsities, deceiving the superficial and the speculative, we have no fears from present indications that the votaries of physiological science will, as a body, be arrayed in opposition to Christianity.

CHAPTER XVIII.

DIFFERENCES BETWEEN MAN AND THE INFERIOR ANIMALS.

531. I HAVE already treated somewhat of the differences between man and the inferior animals in different parts of this book, and especially in the preceding chapter. But it has been done only incidentally, and the subject demands at our hands a more thorough and systematic investigation. This I propose to do in the present chapter.

532. Lord Monboddo maintained that man is only an improvement on the monkey, occurring as a result from the general tendency to advancement claimed to exist in nature. He seemed to think that man bore a relation to the monkey somewhat like

that which the frog bears to the tadpole, as described in § 167, and that as the tadpole becomes the frog, so the race of man was produced by a change at some remote period of the creation, of the monkey into a man. This ridiculous notion of the erudite but fanciful Scotch philosopher is really but another phase of the more recent theory of gradation, or development, as it is sometimes called, which in different forms is now advocated by so many European philosophers. And, although few, comparatively, adopt this theory definitely and fully, there is quite a disposition among many to obliterate the distinctions by which the Creator has in so marked a manner separated man from the inferior animals. It is well, therefore, that we should have a clear idea of these distinctions.

533. It is often very loosely said that while man is governed by reason, instinct rules in the animal.* If it be meant by this that, as a general rule, reason predominates in man, while instinct does so in animals, the statement is a correct one. But if it be meant that animals are wholly governed by instinct, and that man is distinguished from them as a reasoning animal, it is not correct. For some animals do reason, that is, if making inferences be considered as reasoning. In tracing out the differences between man and animals I shall not attempt to show what the nature of instinct is. This is a great mystery, and all attempts to solve it have utterly failed. I shall content myself, therefore, with pointing out some of the differences between instinct and reason. In doing this it is not always easy to say just where the one begins and the other ends, so intimately are their phenomena often mingled together.

534. The actions of instinct are more unaccountable than those of reason. In the operations of reason we see something of the processes by which results are reached. But it is not so with instinct. For example, as a man travels over an unexplored country, we can understand by what means he obtains a knowledge of the country, in order to guide him on his journey. The processes of his reasoning in regard to this we can comprehend. But when an insect travels with unerring certainty to its place of destination without any guide marks that we can

* Some explanation may be well here in relation to the different uses made of the word animal in different connections. Here it is used in contra distinction to man. So it is used in the expression, man and animals. But as man is in certain senses an animal, whenever we wish to recognize this fact we speak of other animals as the *inferior* animals. And thus in regard to animals, we speak of their higher and lower orders, the higher of course being those that approximate nearest to man.

see,* or when a swarm of bees or a flock of birds wing their flight to distant places, or when bees construct their honey-comb with the exactness of mathematics in obedience to the best principles for such a structure, we cannot understand the processes which lead to the result. It seems to be produced by an impulse from a cause extraneous to the animal, guiding it as if it were a mere machine. The little intelligence of the animal seems to have only an incidental connection with this impulse. It, therefore, merely controls somewhat the circumstances under which the instinct acts.

535. So little has the intelligence to do with the instinct, and so nearly mechanical therefore are the actions of the latter, that they are governed by an invariable rule. It is as invariable almost as are the movements of a machine. For this reason there are no improvements or alterations in the acts of instinct. The bird and the bee, for instance, have no change of fashion in their architecture from age to age. The honey that fed John the Baptist, or that which was found by Samson in the carcase of the lion, was deposited in the same hexagonal cells

* I will introduce here as an illustration, a little incident recorded in my note book many years ago. The account of it runs thus: I was much entertained to-day in watching the movements of a very small winged insect—about one-third of the size of a common fly. He was dragging a dead spider across the road. Every now and then he would drop his load, and run forward a little, springing about here and there, and then would go back and take up his load again. His movements in this way were so quick and apparently so irregular, that they seemed to be without an object. But I observed, that although he thus ran about here and there, his course in its general bearing was a very straight one. Soon a waggon passed along directly over where the insect was, separating him from his load, and disturbing the whole surface of the ground. He, however, soon found his load, and then with a good deal of apparent reconnoitering he went on again in the same general course. In the latter part of his journey he travelled over and amidst a heap of stones. Here he would occasionally leave the spider and disappear, and then return again to take his load. Again a little farther on I would see him emerge from his concealed pathway, and so on to the end of his journey. His place of destination was a hole in the sand beneath a flat stone. Now, how did this insect in his journey to his home, (which to him was a long one, though only three rods,) manage to keep so straight a course? Was it in the same way that men manage in their journeys, guided by way-marks, and by information obtained from others? Following out this idea, suppose then a man to be at the same distance from his home *in proportion to his size* that the insect was from his home. According to this supposition he must be over three thousand miles from home. Suppose the direct line to his home lay across an uninhabited country, so that he can get no information from others. This makes his case parallel with the insect's, for we saw him meet no other insects on the road. Now, if he knew the exact direction in which his home lay, he could not, without his compass, move with any precision towards it. And if he had wandered away from it without a compass, as the insect did from his home, how would he know in what direction it lay? And yet the insect travelled towards his home as if he preserved exactly amid all his wanderings the points of the compass. The surface over which he went was very irregular. He had to cross or wind around eminences, which were to him as large as hills and mountains are to man, and yet he was not embarrassed; and when he went among the stones he had more and greater difficulties to encounter than man meets with in passing through the wildest countries. Again, suppose that the travelling man should meet with some whirlwind or some convulsion of nature, which should separate him from his burden, and disarrange in some measure the face of the country about him, just as the travelling insect was served by the commotion of the horse's feet and the wheels of the waggon. Would he find his load as easily as the insect did, and go on his way with as little hesitation?

which are constructed by the bees of the present day. And each bird builds its nest precisely in the same way that its an-

FIG. 187.

NEST OF THE BAYA.

cestral birds have ever done. Most birds' nests are constructed after the same general pattern. But sometimes we observe striking peculiarities to subserve some special purpose. Fig. 187 represents the nest of the Baya, a little bird of Hindoostan. It is in the shape of a bottle, and is made of long grass. It is suspended from a slender branch of a tree, so that monkeys, serpents, &c., cannot reach it. The entrance to the nest is made on the under side, so that these animals cannot enter, while the bird itself can readily fly in. It is divided into apartments, in one of which the female sits upon the eggs, while in the other the male bird "solaces his companion with his song whilst she is occupied in maternal cares." In Fig. 188 is seen the nest of another little eastern bird, which with filaments of cotton taken from the cotton plant, sews leaves together with its beak and feet, so as to conceal the inclosed nest from its enemies.

FIG. 188.

NEST
of the Tailor Bird.

Contrivances in the honey-comb. Mathematical principles exactly applied.

536. While there is no change in the acts of instinct they are marked by perfection. That is, they are perfectly adapted to the purposes to be effected and to the circumstances under which they are performed. The Creator, who directs the impulse that governs the animal, in this case as well as in all others, accurately fits the means to the ends to be accomplished. There is nothing in which this perfection of instinct is better shown than in the construction of the honey-comb. The cells are made hexagonal, because in this way all the space is occupied—there is no waste of room. If the cells were made circular, there would not only be a waste of room, but a large quantity of material would be needed to fill up the spaces between the cells. The difference can be seen in the two Figures 189 and 190. Each comb, it is to be observed farther, has two

FIG. 189.

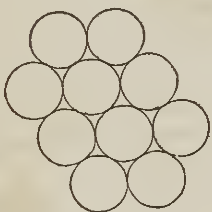
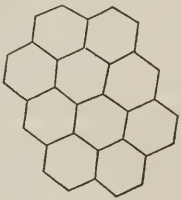
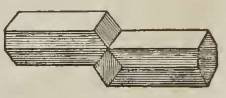


FIG. 190



sets of cells, the ends of one set being arranged against the ends of the other in a peculiar manner. These ends are not flat, but each one has three plane surfaces, forming with each other a particular angle soon to be noticed, and uniting together at the centre in a point. In the arrangement of these cells, therefore, a cell of one set does not lie end to end with a cell of another set. Its three surfaces form a part of the bottom or end of three cells of the other set. This is made clear by Fig. 191, in which a cell of one set is represented as it abuts against a cell of the other set by one of its surfaces, its other two surfaces forming a third part of the ends of two other cells. Now it has been found that the angle formed at the edge of these surfaces between the two sets of cells is such as to secure the greatest strength with the least amount of material. It was at one time thought that

FIG. 191.



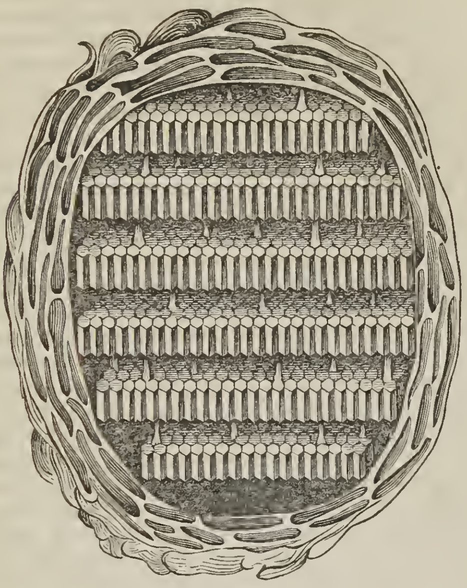
this was proved to be not exactly true. The variation from the correct angle, made out by the calculations of the mathematicians, was indeed a slight one, but still it was variation enough to show, if the calculations were correct, that the workings of instinct were not perfect in this case. But the investigations of Lord Brougham have satisfactorily shown that the mathematicians were wrong in their calculations, and that the bees are right.

537. The perfection of the operations of instinct is shown in the most wonderful manner in the regulation of *communities* of animals. Here we see coöperation to produce results effected through an irrational, and therefore in some measure a blind instinct. This social instinct is most extensively exemplified among the insect tribes, as for instance the bee and the wasp. The structures, resulting from the coöperation of multitudes of little laborers guided by this instinct, are very interesting. I shall allude to but a single familiar example, the construction of the nests of wasps. These insects make their building material from the fibres of old wood. These they convert by mastication into a pulp, which made into a thin layer, becomes firm like paper. It is indeed a process very much like the common process of paper-making invented by man, and the first rude inventor may have got his idea from the insect. With this substance the wasps build several ranges of cells, which are hexagonal, like the cells in the comb of the bee. These ranges of cells are placed parallel to each other, at regular distances, with little supporting columns between them, as seen in Fig. 192.

The number and variety of instincts of the ordinary hive bees are very wonderful, but it would occupy too much space to describe them.

538. The wonderful coöperation of animals in obedience to social instinct, in the building of habitations and other structures is seen in several of the mammalia. But it is most wonderful in the beaver, the following description of whose habits in this respect I take from Carpenter. "During the summer it lives solitarily in burrows, which it excavates for itself on the borders of lakes and streams; but as the cold season approaches it quits its retreat and unites itself with its fellows, to construct, in common with them, a winter residence. It is only in the most solitary places that their architectural instinct fully develops itself. Having associated in troops of from two to three hundred each, they choose a lake or river, which is deep enough

FIG. 192.



NEST OF WASPS.

to prevent its being frozen to the bottom; and they generally prefer running streams, for the sake of the convenience which these afford in the transportation of the materials of their erection. In order that the water may be kept up to a uniform height, they begin by constructing a sloping dam; which they form of branches interlaced one with another, the intervals between them being filled up with stones and mud, with which materials they give a coat of rough-cast to the exterior also. When the dam passes across a running stream, they make it convex towards the current; by which it is caused to possess much greater strength than if it were straight. This dam is usually eleven or twelve feet across at its base, and is enlarged every year; and it frequently becomes covered with vegetation, so as to form a kind of hedge.

539. When the dam is completed, the community separates

into a certain number of families; and the beavers then employ themselves in constructing huts, or in repairing those of a preceding year. These cabins are built on the margin of the water; they have usually an oval form, and an internal diameter of six or seven feet. Their walls are constructed, like the dam, of branches of trees; and they are covered, on two of their sides, with a coating of mud. Each has two chambers, one above the other, separated by a floor; the upper one serves as the habitation of the beavers, and the lower one as the magazine for the store of bark, which they lay up for their provision. These chambers have no other opening, than one by which they pass out into the water. It has been said that the flat oval tail of the beavers serves them as a trowel, and is used by them in laying on the mud of which their erections are partly composed; but it does not appear that they use any other implements than their incisor teeth and fore-feet. With their strong incisors they cut down the branches, and even the trunks of trees which may be suitable; and by the aid of their mouths and fore-feet, they drag these from one place to another. When they establish themselves on the bank of a running stream, they cut down trees *above* the point where they intend to construct their dwellings, set them afloat, and, profiting by the current, direct them to the required spot. It is also with their feet that they dig up the earth they require for mortar, from the banks or from the bottom of the water. These operations are executed with extraordinary rapidity, although they are only carried on during the night. When the neighborhood of man prevents the beavers from multiplying to the degree necessary to form such associations, and from possessing the tranquillity which they require for the construction of the works just described, they no longer build huts, but live in excavations in the banks of the water."

540. Instinct moves straight on to its result, and it does so blindly. It exercises no intelligence in regard to the purpose for which the result is intended, or the circumstances which tend to defeat this purpose. It evidently in some cases never knows any thing of the purpose aimed at by its acts, as, for example, when an animal makes provisions for a progeny which it is never to see. "It is scarcely possible," says Carpenter, "to point to any actions better fitted to give an idea of the nature of instinct, than those which are performed by various insects, when they deposit their eggs. These animals will never behold their progeny; and cannot acquire any notion from ex-

perience, therefore, of that which their eggs will produce; nevertheless they have the remarkable habit of placing, in the neighborhood of each of these bodies, a supply of aliment fitted for the nourishment of the larva that is to proceed from it; and this they do, even when they are themselves living on food of an entirely different nature, such as would not be adapted for the larva. They cannot be guided in such actions by any thing like *reason;* for the data on which alone they could reason correctly, are wanting to them; so that they would be led to conclusions altogether erroneous if they were not prompted by an unerring *instinct*, to adopt the means best adapted for the attainment of the required end."

541. The results of reason are often mingled with those of instinct in such a way that it is difficult to distinguish them from each other. But instinct is of itself wholly *irrational.* If it were not so, it would avoid acting whenever action would evidently be useless. But instinct has not the eyes of reason to see when this is the case. It leads the animal blindly on; so that, although under all *ordinary* circumstances the object is accomplished definitely and in the best manner, yet there is no capability of making provision for *extraordinary* circumstances. Therefore, actions are occasionally performed, which do not at all answer the purpose which the instinct is designed to effect. Instinct, though perfect in its action under the fixed uniform circumstances under which it is destined to act, is a kind of blunderer when irregular circumstances arise. Instinct is a strict routinist, while reason readily accommodates itself to endlessly varying circumstances. In illustration of the above characteristic of instinct, I will cite a few examples. The hen will sit on pieces of chalk shaped like eggs, as readily as she will on the eggs themselves. Her instinct is so blind as to be deceived by this general resemblance. The flesh-fly often lays its eggs in the carrion-flower, the odor of which is so much like that of tainted meat as to deceive the insect. An amusing illustration of the blind disregard of circumstances in following out the promptings of instinct is given by a gentleman, Mr. Broderip, in an account of a beaver which he caught when very young. As soon as it was let out of its cage, and materials were placed in its way, it began to build after the fashion followed by these animals when they construct their dam in a stream of water and build their habitations in its banks. "Even when it was only half grown," says Mr. B., "it would drag along a large sweeping-brush, or a warming-pan,

grasping the handle with its teeth, so that the load came over its shoulder; and would endeavor to lay this with other materials, in the mode employed by the beaver when in a state of nature. The long and large materials were taken first; and two of the largest were generally laid cross-wise, with one of the ends of each touching the wall, and the other ends projecting out into the room. The area formed by the cross-brushes and the wall, he would fill up with hand-brushes, rush-baskets, books, boots, sticks, cloths, dried turf, or any thing portable. As the work grew high, he supported himself on his tail, which propped him up admirably; and he would often, after laying on one of his building materials, sit up over against it, appearing to consider his work, or as the country people say, 'judge it.' This pause was sometimes followed by changing the position of the material judged; and sometimes it was left in its place. After he had piled up his materials in one part of the room, (for he generally chose the same place,) he proceeded to wall up the space between the feet of a chest of drawers which stood at a little distance from it, high enough on its legs to make the bottom a roof for him; using for this purpose dried turf and sticks, which he laid very even, and filling up the interstices with bits of coal, hay, cloth, or any thing he could pick up. This last place he seemed to appropriate for his dwelling; the former work seemed to be intended for a dam. When he had walled up the space between the feet of the chest of drawers, he proceeded to carry in sticks, cloths, hay, cotton, &c., and to make a nest; and when he had done, he would sit up under the drawers, and comb himself with the nails of his hind feet." I simply remark in relation to this amusing narration, that you can see at once that if the instinct of this animal had been at all rational, it would not have impelled him to construct a dam and a dwelling in a common room, where they would be of no use to him. Reason would have dictated the building of a nest and nothing more.

542. The care which animals exercise in relation to their progeny seems to be governed to a great extent, perhaps wholly, by a blind instinct. All care is given up when care is no longer needed, and with it what appears to be affection is given up also. In animals there is no such lasting affection of the parent for the progeny as there is in man; for in them it is merely instinctive, and not rational and moral in its character, and it, therefore, lasts only so long as it is needed to carry out the purposes for which this particular instinct is designed.

Indeed, in some cases there can be no affection in all the care which is instinctively exercised by the parent, for it is put forth for progeny which, as stated in § 540, the animal is destined never to see. And in those cases among animals in which the family state exists, it is a mere temporary affair, and as soon as the offspring is able to take care of itself it is no more to the parent than any other animal of the same tribe is.

543. But some animals have intelligence as well as instinct. When this intelligence is shown in the mere power of imitation it is of a low order. The parrot that learns to imitate man in speech is nothing like as intelligent as some animals that have no such power. Some animals have really a *reasoning* intelligence—that is, they make rational inferences. Their reasoning is sometimes, as before remarked, so mingled with the operations of instinct, that it is difficult to distinguish them accurately. In the case of the beaver related in § 541, who labored so faithfully in obedience to a blind instinct, there was some exercise of reason, as, for example, when he "judged" his work. But it is difficult to point out definitely the line between instinct and reason in such a case. There are some animals, however, in whom the workings of a reasoning intelligence are to be seen with perfect distinctness. But their reasoning differs from that of man. The inferences which the reasoning animal makes are individual; while man goes beyond this, and makes general inferences, and therefore discovers general truths. Newton's dog, Diamond, saw apples fall to the ground, as well as his master. And he was capable of making some inferences in regard to them; but they were individual inferences. For example, if an apple-tree were shaken, and the dog were hit by a falling apple, whenever he saw other apples falling he would infer that he might be hit again, and would infer also that it was best for him to get out of harm's way. This would be the extent of his reasonings. But his master inquired into the cause of the fall of the apple, and by considering this and other similar phenomena, he deduced general principles, which govern the movements both of the atoms, and the worlds of the universe.

544. The inferences which are formed by animals are mere results of the association of ideas, and the process, therefore, really hardly merits the appellation of reasoning. Thus, in the case of Newton's dog, supposed above, the idea of the falling apples was associated in his mind with the hurt experienced when he was hit, and prompted the getting out of harm's way.

When such associations are extended and complicated, it appears at first thought as if the animal acted in view of general truths, arrived at by the same process of reasoning that man employs. But it is a mere extension of mental associations. Thus, Newton's dog probably associated the idea of being hit and hurt with other falling bodies beside apples. And so, too, various circumstances might come to be associated with the falling of bodies, and thus complicate the mental process which occurred when he saw any object falling near him.

545. To show somewhat the extent to which this mental association operates in the brute mind, I will allude to some examples. A wren built its nest in a slate quarry, where it was liable to great disturbance from the blastings. It soon, however, learned to quit its nest, and fly off to a little distance, whenever the bell rang to warn the workmen previous to a blast. As this was noticed, the bell was sometimes rung when there was to be no blast, for the sake of the amusement in seeing the poor bird fly away when there was no need of alarm. At length, however, it ceased to be deceived in this way, and when it heard the bell ring it looked out to see if the workmen started, and if they did then it would leave its nest. In this case the bird merely learned to connect in its mental associations two circumstances with the blasting, instead of the one from which it at first took the warning. The operation of this mental association is shown in a little different manner in the following case. Some horses in a field were supplied with water in a trough which was occasionally filled from a pump. As the supply was not always sufficient, one of the horses, more sagacious than the rest, whenever he, on going to drink, found the trough empty, pumped the water into it by taking hold of the pump-handle with his teeth, and moving his head up and down. The other horses seeing this, would, whenever they came to the trough and found it empty, tease the one that knew how to pump, by biting and kicking him, till he would fill the trough for them. In this case the horse that did the pumping *associated* in his mind the motion of the pump-handle, as he had seen it done by his master, with the supply of water. And while they *associated* this supply with his pumping, he knew what their teasing him meant, because he *associated* it with their motions about the trough, indicating so plainly that what they wanted was water. But I will give a still stronger case. A dog belonging to a Frenchman was observed to go every Saturday, precisely at two o'clock, from his residence at

Locoyarne to Hennebon, a distance of about three quarters of a league. It was found that he went to a butcher's, and for the purpose of getting a feast of tripe which he could always have at that hour on Saturday, their day of killing. It is also related of this dog, that at family prayers he was always very quiet, till the last *paternoster* was commenced, and then he would uniformly get up and take his station near the door, in order to make his exit immediately on its being opened. The narrator of these facts thinks that the first fact shows, that the dog could measure time and count the days of the week. But this cannot be so. The dog undoubtedly associated in his mind the time at which he could get the tripe, with something that occurred on Saturday at that hour at his master's house, just as he associated the concluding of family prayers with something that occurred as the last *paternoster* was read, perhaps with some peculiarity in the manner of his master when he came to that part of the service.

546. Animals learn the relation between cause and effect by this mental association, and act upon the experience thus gained. This is manifest in the examples I have cited. And it may be observed in many acts that we witness occasionally in the higher animals. Thus, for example, as my horse was cropping some grass, he took hold of some that was so stout, and yet so loosely set in the ground, that he pulled it up by the roots, and, as the dirt which was on it troubled him, he very deliberately knocked it across the bar of a fence till he got all the dirt out, and then went on to eat it. Here was a knowledge of cause and effect which was derived from previous experience through mental association. You see the same thing when you see a cat jump up and open the latch of a door, or a horse unbolt the stable door to get out to his pasture. But in all such cases the knowledge of cause and effect differs from the same knowledge in man in one important particular. In the animal it is always an individual knowledge, that is, a knowledge of individual facts; while in man it is often a knowledge which has relation to general truths or principles.

547. From the facts stated in the last few paragraphs it is clear, that Carpenter is not correct in saying, that "the mind of man differs from that of the lower animals, rather as to the *degree* in which the reasoning faculties are developed in him, than by any thing peculiar in their *kind*." While there is much in common between them in their modes of mental action, especially if man be compared with other animals in the period

of his infancy and childhood, there is, as you have seen, one attribute of the human mind which is wholly peculiar to it, and never exists in any degree in any other animal. And this attribute, the power of abstract reasoning, or in other words, the power of deducing general truths or laws from collections of individual facts, constitutes the great superiority of the human mind, in distinction from the mind of the brute.

548. It is this attribute which is the source of language in man. This can be readily seen by observing what is the nature of language. It is a collection of corresponding vocal and written signs of an arbitrary character, arranged according to certain general rules or principles. Other animals do have a kind of language of a very limited character. It is the language of natural signs. It is composed of cries and motions, which vary in different tribes of animals, so that each tribe may be said to have its own natural language. But animals never invent and agree upon any arbitrary signs, as is done continually by mankind in the construction and extension of language. This they cannot do, because abstract reasoning is required for such an invention. General principles are observed in the construction and arrangement of arbitrary signs, and, as I have shown, brutes know nothing of principles.

549. This attribute also is the source of man's belief in a Creator. If he had not the power of deducing general truths from individual facts, he could neither discover the truth that there is a first great Cause, nor appreciate or even receive it, if it were communicated to him. Not the faintest shade of such an idea can be communicated to any of the inferior animals, however high their mental manifestations may be, and simply because the structure of their mind is such that they know nothing of general principles. Carpenter speaks of the disposition to believe in the existence of an unseen but powerful Being, which is found to be universal even among the most degraded races of mankind, as a natural tendency, which he seems to think is implanted in the human breast by the Creator. But it appears clear, that it is a mere natural result of the exercise of the power that I have just spoken of.

550. Man differs from other animals also in having a conscience, or, a knowledge between right and wrong, and a sense of obligation in relation to it. This moral sense is supposed by some to be a mere result of the exercise of the power of abstract reasoning. But others suppose that the sense is implanted as a distinct quality or power, and that the office of the

reasoning power in relation to it is to bring the evidence before it for its decision. I shall not discuss this point, but will merely remark in regard to this subject, that there is no doubt as to the existence of such a sense in man. Some attempt to throw doubt over it by pointing to its perversions, maintaining that it is a mere creature of circumstances, varying almost endlessly in different parts of the world. But it would be just as rational to attempt to show, that there is no such thing as a sense of the beautiful in man, by appealing to the evidences of perversions of taste, which ignorance, bad education, and foolish and novelty-loving fashion have induced.

551. In those cases in animals in which this moral sense has been supposed to exist, it is nothing but slavish fear. It has been said by some one that man is the god of the dog; but it is sacred trifling to compare the attachment of an animal to its master and its fear of his displeasure, with the intelligent regard of man for his Creator as a holy and benevolent being. We ordinarily recognize the distinction between man and animals, as to the existence of a conscience, in the language we use. We never attach the idea of moral character to the acts of an animal except by the force of association, and then only slightly and loosely. We are not apt to speak of *punishing* a dog, for this word implies a moral fault as the occasion of the infliction. We *whip* him, sometimes, simply to associate in his mind the smart with the act done, so as to prevent him from doing it again, and sometimes to vent our ill feeling for the harm done us on the poor dog that has so innocently done it. It is related of Sir Isaac Newton that he had a favorite little dog called Diamond, who being left in his study, overset a candle among his papers, and thus burnt up the almost finished labors of many years, and yet the philosopher only said, "O Diamond! Diamond! thou little knowest the mischief thou hast done." Newton was both a wise and a good man, and while he saw that whipping the dog would do no good in preventing any similar accident in future, he had no ill feeling to vent on poor Diamond, who certainly had a better and more rational master than most dogs have.

552. The mental distinction between man and animals may be thus summed up. The animal is governed by instinct, and in the higher orders by a kind of reasoning which is based upon mental association. Man has, in addition to instinct and this lower order of reasoning, the power of abstract reasoning. In the lower orders of animals probably instinct rules alone. In

them there is none even of the limited reasoning which we see in the higher animals. They have a nervous system with certain central organs, but have really no one great central organ that we can call the brain. As we trace the animal kingdom upward, we soon find that a brain appears, that is, such an organ as may be considered the chief centre of the nervous system. And then, as we continue to trace upward in the scale, we find that the more intelligence or reasoning there is, the more prominent is the brain in proportion to other parts of this system. When we come to man the brain is much larger than in any other animal, and his intelligence is not only greater, but it is of a different character. Not only is the amount of his reasoning by association greater than in other animals, but there is also superadded, as his grand distinguishing mark, the power of abstract reasoning.

553. Instinct, you have seen, cannot be improved by education. It always acts in the same way throughout the life of an animal, and through the succeeding generations of the tribe. It has no accumulated experience, either individual or traditional. But it is otherwise with the two kinds of reasoning power. These can be educated, and they have an experience. But here there is a marked difference between the two kinds of reasoning. The lower kind of reasoning, that of mere association, which is the only kind possessed by animals, is altogether individual, and is not at all traditional. However wise an animal may become, there is no transmission of his wisdom to his posterity. No animal can start from a point of knowledge gained by his ancestor, as a vantage ground, and thus make greater advances than his predecessors. Each animal, in acquiring experience as to the relations of cause and effect, has to begin at the beginning, and learn every thing for himself. The higher form of reasoning, that which man alone possesses, is absolutely essential to the transmission of experience from one generation to another. It is necessary to the transmission even of that experience which is gathered by the other power of reasoning, as well as that which is gathered by itself. The amount of improvement which can be effected where there is only the lower kind of reasoning to act upon, is very wonderful in the case of some of the docile animals. The dog, the elephant, the monkey, &c., are familiar examples. By the skillful and persevering use of mental association in the training of animals, results can be obtained, that resemble very closely those which come from man's power of abstract reasoning.

And in some cases the animal accumulates quite a large individual experience. But his race is none the wiser for it. It is none of it transmitted to another generation.

554. We see then the basis of improvement in man. It is not his power of making inferences merely. The brutes do this. It is his power of making general inferences, or, in other words, deducing general laws or principles from individual facts. And as this power distinguishes man from the inferior animals, so a superior degree of it ordinarily constitutes the intellectual superiority of one man to another. This is seen very readily in inventions and discoveries. In the case of almost every invention or discovery, the individual facts upon which it is based were known to many others, perhaps even a long time before the invention or discovery was made. The merit of the inventor or discoverer consists in having seen the available general truth indicated by the facts, and traced out its application to certain objects to be attained. Thus, to take a single example, dairymen and dairywomen in great numbers knew the fact, that a certain disease, derived from the cow accidentally by individuals, prevented them from taking the small pox; but Jenner was the first to see, that here was developed a great general fact, capable of universal application. And thus seeing the wide scope of the fact, he collected the proofs of it, and devised the means by which it could be made available to prevent the ravages of one of the great scourges of the race. It was by the generalizing power of his reasoning that he went beyond dairymen and dairywomen, and became the discoverer.

555. It is interesting to observe that while the capabilities of instinct are developed rapidly, sometimes almost instantaneously, the capabilities of the reasoning power are developed gradually. Especially is this the case with the higher reasoning power, that distinguishes man from the brutes. The child is governed at the first wholly by instinct; and then as he gathers knowledge of the world around him through his senses, mental association comes into play. By the exercise of the lower kind of reasoning, which he has in common with animals, he accumulates experience of the relation of cause and effect. Thus far he is on common ground with animals, that is, those of the higher orders, except that he adds more largely to his experience from mental association than they do. Meanwhile the power of abstract reasoning is gradually developed, raising him up from the level of the brutes, and introducing him into companionship with the whole intelligent creation, even with God him-

self, whose image he bears in possessing this attribute. This power of generalizing facts is developed earlier than is generally supposed. It is of course feeble at first, and has a narrow range; but it very early shows itself sufficiently to indicate to us clearly, that the child's mind differs essentially from that of the brute. And when disease or original physical defect prevents its development, we see the mental deficiency, and the consequent resemblance of the child in mental character to the inferior animals.

556. When this characteristic power of the mind of man is fully developed, its achievements are often so wonderful, that they give us some realization of the great truth, that man is created in the image of God. As we witness the demonstration of such facts as Newton discovered, or the unerring calculations of an eclipse, or listen to a perfect argument as it develops grand truths, and leads us with a majesty of thought almost divine, straight on to mighty conclusions, we take in the full meaning of the assertion, that "the soul is that side of our nature which is in relation with the Infinite," and we see the folly of those dreamers in science, that look upon man as making merely the highest order in the animal kingdom. We see that the chasm between him and other animals is truly "impassable." We see that we are in a mental region of which the most intelligent of them know nothing—that though they live like us, having the same senses, seeing the same beautiful things, and hearing the same voices of nature, and like us have thoughts and emotions and desires, they are shut out from an upper region of thought and feeling in which we freely roam, and from which we look with aspirations unknown to them to another world beyond.

557. As the mental capabilities peculiar to man are slowly developed, so it is with his physical frame, and the powers that belong to it. Though man at length so excels all other animals, that they are subject to his power as their master, he is at the first the most helpless of all animals. He is a long time "in the nurse's arms," and for years he is unable to obtain his own food. He does not reach the full strength of his body and mind till he is more than twenty years of age. He is in strong contrast with other animals in regard to this slowness of development, they generally reaching their full capabilities in a short time. But even among them, it is to be observed, that there is a difference in this respect, in obedience to a general law, that the higher the capabilities are, the slower they are in their development.

558. The differences between the physical endowments of man, and those of the higher orders of animals, are often very minutely described. But though strongly marked, too much prominence is ordinarily given to them. They should be considered as subordinate altogether to the mental differences. Thus, much is often said of the superiority of man in regard to the possession of a hand, on which I have remarked in various parts of this book. But why should he have such an instrument given to him? Simply because he has a mind which is not only capable of directing it, but which needs such an instrument to produce suitable results in its action on the world around. If other animals had a hand they could not use it properly. They have instruments of a different character, of less various capabilities, but such as are suited to their wants and powers. The same thing can be said of other bodily endowments. They are always suited in range and power to the wants and mental capabilities of the animal. As we trace out this general idea, we find that some animals have some bodily endowments which far excel the same in man. Thus, some have greater powers of vision and hearing than he has, because they need them. So, too, some have endowments of which we find no trace in man, as, for example, the power of flying. For the same reason most animals have special natural means of defense against the attacks of other animals; but man has not, because he has no need of them, as by his ingenuity he can contrive such means as he may require.

559. The physical endowments of man in comparison with animals are indeed wonderful, and correspond with his spiritual endowments, so far as gross matter can compare with subtle immaterial mind. We have looked at these endowments in detail in various parts of this book. Let us glance at the principal of them collectively. As the muscles are the organs by which all communication between man and man, and indeed all action upon the external world is effected, it is in the endless combinations of muscular action that man is most signally superior to animals in physical endowment. This is shown, as you have seen, in the human hand, whether it be looked at as an instrument for work or for expression. The same thing we see exhibited almost as strikingly in the muscles of the voice—both those which by their delicate and accurate action regulate the vocal ligaments, and those which by their complicated action give the voice all its variety of articulation, especially the latter. But let us look at the body as a whole. Man walks erect, a

significant characteristic of him as differing from animals. And though there be grace of movement in many animals, it is not in any case to be compared with that which we see exhibited by the erect human form. The extreme variety of combination in the action of the muscles in man is one cause of this superiority. But another and the chief cause is the impress of beauty given to graceful action by the mind. Almost all muscular action speaks to us a language that comes from the thought and feeling at work within, even when it is unintended; and this is the source of a large portion of the enjoyment that we receive, for the most part unconsciously, from the graceful movements that we witness in our fellow men. And when in a beautiful and graceful form we come to add to the ordinary movements of the body, which are commonly, though improperly, considered as meaningless, those movements which are distinctively expressive of thought and emotion, we are filled with admiration of the wonderful capabilities of the human frame in graceful action.

560. The human form in repose, when in its greatest perfection, far transcends, as a combination of varied beauty, any thing that we see in the inferior animals. But its superiority in this respect is best seen when the intelligent and feeling mind puts it into action. And this is especially true of those parts which are most engaged in expression—the hand with its endlessly varied movements, but most of all the face. It is in this noblest part of the human frame that the soul of man, through the subtle agency of the nerves, most strikingly imprints its immaterial qualities upon a material form, and exhibits the highest graces of motion in the delicate and ever varying play of the muscles. And when in the impassioned speaker, while the muscles of the voice and articulation are executing their exceedingly rapid and complicated movements, we see the whole frame in its motions and attitudes brought into consonance with the burning words and the beaming countenance, we take in the full idea of the adaptation of the human body to the mind that tenants it. Though the hand is commonly spoken of as affording the best illustration of man's superiority to other animals in muscular action, it is far from being as impressive an exhibition of it as this action of the whole frame. It is when the mind, through the numberless nerves that connect it with every part of the body, brings them all into its service in expression, that we get the most exalted conception of the excellence of the human organization.

CHAPTER XIX.

VARIETIES OF THE HUMAN RACE.

561. ALTHOUGH, as we look at men of different nations, we find that there is a general agreement in form and organization, there are many points in which they strikingly differ from each other. "With those forms, proportions, and colors," says Mr. Lawrence, "which we consider so beautiful in the fine figures of Greece, contrast the woolly hair, flat nose, thick lips, the retreating forehead, advancing jaws, and black skin of the negro; or the broad square face, narrow oblique eyes, beardless chin, coarse straight hair, and olive color of the Calmuck. Compare the ruddy and sanguine European with the jet black African, the red man of America, the yellow Mongolian, or the brown South Sea Islander; the gigantic Patagonian to the dwarfish Laplander; the highly civilized nations of Europe, so conspicuous in arts, science, literature, in all that can strengthen and adorn society, or exalt and dignify human nature, to a troop of naked, shivering, and starved New Hollanders, a horde of filthy Hottentots, or the whole of the more or less barbarous tribes, that cover nearly the entire continent of Africa;—and although we must refer them all to the same species, they differ so remarkably from each other as to admit of being classed into a certain number of great varieties; but with regard to the precise number, naturalists have differed materially." Cuvier admitted but three varieties, the *Caucasian*, *Negro*, and *Mongolian.* The more commonly received classification, however, is that of Blumenbach, who makes five varieties, viz., the *Caucasian*, *Ethiopian*, *Mongolian*, *American*, and *Malay.*

562. The chief characteristic of the *Caucasian* variety is the fine form of the head, it being nearly oval, as you view it from the front. It is also characterized by a great range of variations of the color both of the skin and the hair. There has been more of civilization and improvement of every kind in this race than in any of the others. It is mentally superior to the other races. It is called Caucasian from Mount Caucasus, from the vicinity of which, it is supposed, it originated. Even at the present day it is said that the characteristics of this race are

most perfectly developed in the Georgians and Circassians, who live in the neighborhood of this range of mountains, and who are considered the handsomest people in the world.

563. The *Ethiopian* variety is quite in contrast with the Caucasian. The organization has not the perfection and elegance which the Caucasian presents, and it shows an approximation to the higher orders of the inferior animals. The skull is small. The forehead is retreating, while the face below is projecting, the cheek bones being prominent, and the nose broad. The apparatus of the senses is thus fully developed, while the brain is less than in the Caucasian. The hair is black, oily, and frizzled. It is commonly said to be woolly, but it is really not so. Dr. Carpenter says that "microscopic examination clearly demonstrates that the hair of the negro has exactly the same structure with that of the European, and that it does not bear any resemblance to wool save in its crispiness and its tendency to curl." The skin is generally black; but not so in all the race, for the Caffirs and the Hottentots are yellow.

564. The *Mongolian* variety, of which the Chinese race forms the largest family, is characterized by prominent broad cheek bones, flat square face, small oblique eyes, straight black hair, scanty beard, and olive skin.

565. The *American* variety is characterized by high cheek bones, a narrow low forehead, features large and bold, except the eyes, which are deeply sunken in large sockets, hair generally black, stiff and straight, and complexion varying from a crimson brown to a deep copper.

566. The *Malay* variety, which occupies the Islands south of Asia, in the Indian and Pacific oceans, has not so well marked characteristics as the other varieties. The complexion is brown, varying from a light tawny to almost black, the hair is black and thick, the forehead is low and round, the nose is full and broad, the nostrils wide, and the mouth large.

567. Other classifications have been made, in some of which the human race is divided into many more varieties. Any classification must be in a great measure arbitrary, and must be regarded rather as a convenience, than as having the definite and invariable character which belongs to truly scientific distinctions. In each of the five divisions of Blumenbach there is great diversity. Thus, in the Caucasian variety, the English, the French, the German, the Irish, &c., are quite distinct from each other. And we sometimes see very striking characteristic marks separating single families from others. The

varieties of the race are thus almost endless, the lesser differing only in degree from the larger.

568. The *national* differences are evidently produced by causes of very much the same character with those which produce differences in individuals and families. And the question arises whether such differences as those which Blumenbach describes as marking the races, are not produced in a similar manner. This question has been much discussed, and there is great difference of opinion in regard to it. The great majority of naturalists believe in the unity of the origin of the human race, and hold that its varieties are the results of the various circumstances by which man has been surrounded. But some suppose that the different varieties come from separate pairs created by God in different localities, and hold that the history in Genesis is a history of the origin of only one of the varieties of the race. Those who advocate this doctrine are few in number; but it has acquired greater currency of late, because one of the most eminent naturalists of the present day, Professor Agassis, has espoused it. His doctrine on this subject I will give as briefly as possible.

569. All animals, he asserts, like plants, have particular localities, for which they are fitted, and to which they belong. These zoological provinces, as he terms them, are of unequal extent, some animals having a wider range than others. From this general law of distribution, which he illustrates with many facts, he infers that the various animals on the face of the earth were not created in one part of the earth and distributed from this to other parts, but were created in the provinces to which they belong. This view of the subject forces itself upon the mind of the naturalist, as he observes the arrangement of the various tribes of animals on the earth's surface. And besides, there are apparently insurmountable difficulties in the way of a diffusion of animals over the globe by means of migration. For example, we cannot conceive how the polar animals could have migrated over the warmer tracts of land, which they would have to cross according to this supposition, for it is impossible now to keep them alive under such circumstances with the greatest precautions. And farther, some animals of the same species, sometimes presenting varieties and sometimes not, are found in different localities which are so cut off from all communication with each other, that it is impossible that these animals could migrate from some one locality to all the rest. "To assume," he remarks, "that the geographical distribution of

such animals, inhabiting zoological districts entirely disconnected with each other, is to be ascribed to physical causes, that these animals have been transported, and, especially, that the fishes which live in fresh water basins have been transported from place to place—to suppose that perches, pickerels, trouts, and so many other species found in almost every brook and every river in the temperate zone, have been transported from one basin into another by freshets or by water birds—is to assume very inadequate and accidental causes for general phenomena." Not only then were different species of animals created originally in different localities, but it is also true to a considerable extent, that animals of the same species occupying different localities were created in those localities.

570. All this he claims to be consistent with scripture, and with very good reason. The account of the preservation of animals in the ark, interpreted according to the common license of language, indicates really only such a preservation, as would be necessary for the stocking of that part of the world where Noah and his family were, after the waters should subside. The number and the variety of the animals preserved for this purpose would of course be very great, and would, according to the common usage of language in narration, be spoken of in the terms used in the Bible. This interpetation holds equally, whether the deluge be considered as having been partial or universal.

571. The case being thus quite clearly made out in relation to animals generally, he proceeds to trace an analogy between them and the races of man in this respect. He supposes that there are certain zoological provinces for the different human races, as there are for the different species and varieties of animals; and that these races were separately created in these provinces with organizations suited to their peculiar localities. While he allows that climate and other influences affect the varieties of the human race, he claims that they are not competent to produce them alone; and he infers, therefore, that there must have been, as in the case of animals, different original creations in the different zoological districts. He accordingly claims that the history given in Genesis is a history of the origin of only one branch of the human family. He does not suppose that the different branches constitute different species, but are made varieties of one species.* He characterizes mankind

* The difference between *species* and *varieties* is this. The distinction of *species* rests upon *specific* characteristics, that cannot be changed by those influences which tend to

as being every where essentially the same in mental character, and alike the accountable subjects of God's kingdom, notwithstanding their multiple origin. It is in this respect that he considers them as being of one brotherhood, and he looks upon the expression in the Bible, "made of one blood," as being entirely figurative, and as referring to "the higher unity of mankind, and not to their supposed connection by natural descent."

I do not propose to go into a thorough discussion of this question. This would not be possible in the narrow limits of a chapter. I shall only present a general view of the chief facts and arguments that bear upon the point at issue. And let us look at this subject first in the light of physiology and natural history.

572. The great majority of physiologists and naturalists, as I have before remarked, have thus far been of the opinion that the human race came from one origin, and that the varieties of it have been produced by the various influences to which man has been subjected. These are commonly included in the general expression, *climatic and other influences.* To be more particular, they are—climate, situation, food, clothing, customs, habits, way of life, state of civilization. Too great prominence has been undoubtedly given to the influence of climate. Lawrence very justly remarks in his general conclusions in regard to the production of the varieties in man and animals, "that of the circumstances which favor this disposition to the production of the varieties in the animal kingdom, the most powerful is the state of *domestication.*" This word, as he uses it, includes all those social inflnences, which as manifestly affect the animals which man domesticates as they do man himself. The analogy between man and animals in relation to the results of the influences referred to I shall soon speak of more particularly.

573. That climatic and other influences do have a very great agency in producing the varieties both individual and general, that we see on looking over the human family, no one doubts. The only question is, whether they have produced *all* these differences—whether, for example, they have occasioned that

produce the differences thnt make *varieties.* The characteristics nf a species are *original*, while those of a variety are *acquired.* "The term species," says Prichnrd, "includes only the follnwing conditions, nnmely, sepnrate origin and distinctness of rnce, evinced by the constant trnnsmission nf some characteristic peculiarity of orgnnization. A race of animals or of plnnts marked by any peculinrity which it has ever constantly displayed, is termed a species; nnd two rnces are considered specifically different, if they are distinguished from each other by some characteristic which the nne cannot be supposed to have acquired, or the other to have lost, through any known operation of physical causes."

very wide difference that we see between the Caucasian and the Ethiopian. My limits will not allow me to go into a full examination of the influence of these causes, and I can only touch upon a few points in a very general way.

574. That climate has a great influence upon the color of the race is proved by many clearly observed facts. Tropical heat always has a tendency to produce a black skin. This is shown very decidedly in the case of the Jews, who have preserved their characteristic features amid varieties of climate, and yet have their color altered. Thus, while the Jew of the interior of Europe has a fair complexion and light hair, under the scorching sun of India his hair is crisped, and his skin is black. The evidence of the influence of climate is the stronger in this case, because the change from the original color has been two-fold. For the original Jew in Palestine had undoubtedly a dusky skin and dark hair, upon which the temperate climate of the interior of Europe, and the tropical climate of India have produced two opposite effects.

575. But in the varieties of the human race there are differences of form as well as of color. That the various influences to which man is subjected have a marked effect upon his physical form is universally acknowledged. We see this alike in individuals, families, and nations. Intellectual and moral influences manifestly exert some influence in moulding the shape of the head in the individual. The differences, which we so commonly see in the shape of the head between the intellectual and the ignorant, are not owing altogether to original difference of capacity, but in part to education. The brain, like all other organs in the body, is influenced in its development by the degree of activity to which it is stimulated. It is not made an exception to this general law of development. Accordingly we find that depressing influences tend to make the top of the head, the cerebral part, small, and the forehead retreating, while the face, from the predominance of the sensual over the intellectual, is rendered relatively too prominent. The tendency of elevating influences is of an opposite character. And such influences, thus operating in the individual, when repeated and accumulated from generation to generation, produce great and lasting results. It is thus that a race becomes either degraded or elevated. By a continuance and accumulation of influences it acquires either a good or a bad fixed character.

576. I have thus spoken of one class of causes effecting changes in the physical form, the influence of which is manifest.

But there are changes seen, the causes of which we cannot clearly make out; and yet we know that they are occasioned by the varying circumstances in which man is placed. By the compound influence of many causes combined we continually see differences in the shapes of various parts of the body introduced. Family and national peculiarities are thus occasioned. The influences to which I have thus referred, some of which are little understood, are all those which Mr. Lawrence includes in the term *domestication*, which, as I have before said, he applies to man as well as to animals.

577. Dr. Prichard has pointed out three different types of form in the head, occasioned by three distinct classes of influences. One he terms the *prognathous*, (a word derived from two Greek words meaning *before* and *the jaw*,) in which the jaws project very prominently forward. This formation is characterized by the predominance of the sensual over the intellectual, the apparatus of the senses being largely developed, while the cerebrum is small, making the forehead retreating. The tendency to assume this type is always in proportion to the action of the degrading influences. "Want, squalor, and ignorance," says Carpenter, "have a special tendency to induce the diminution of the cranial portion of the skull, and that increase of the facial, which characterize the prognathous type." It is seen most strongly marked in the negroes of the Gold Coast. In the *pyramidal* type, as it is termed, the cheek bones are very broad, and the bones above are so shaped as to give the top of the head a sort of pyramidal form. This type we see in those tribes that lead a wandering life—the *nomadic races*, as they are called. The *oval* or elliptical form, which is seen so well marked in the Caucasian variety, is manifestly the result of elevating influences. These types are convertible into each other. Thus, the oval may be degraded into the prognathous, or the prognathous may be elevated into the oval. The latter change is seen in the Ethiopian, when in successive generations he is subjected to elevating influences, in his intercourse with the Caucasian. And it is interesting to observe that the form of the head is more readily changed than the color. "Thus," says Carpenter, "in some of the older West Indian colonies, it is not uncommon to meet with negroes, the descendants of those first introduced there, who exhibit a very European physiognomy; and it has even been asserted that a negro belonging to the Dutch portion of Guinea may be distinguished from another belonging to the British settlements, by the similarity of the

features and expression in each, to those which peculiarly characterized his master's. The effect could not have been produced by the mixture of bloods, since this would be made apparent by alteration of color." In the same way is the pyramidal type convertible with the others. The pyramidal and the prognathous are often mingled together, by the influence of vagabond habits and degrading causes.

578. The view thus given of the operation of influences in producing the varieties of mankind is strengthened by the fact that, as Humboldt says in his Cosmos, there are "many *intermediate gradations* in the color of the skin and in the form of the skull." If we look alone at the *extremes* in varieties of color and form, we are of course disposed to regard such great differences as marking a distinction of species. But when we see these varieties passing into each other by such insensible gradations, and at the same time observe the manifest influence of causes upon these gradations, as in the cases referred to in the last paragraph, the evidence is clear to us that the varied influences brought to bear upon man are competent to produce the varieties of the race.

579. But it is objected that although climatic and other influences have a great effect, yet, so far as we can see, they only produce changes that approximate to those differences that mark the grand divisions of the race. They cannot, for example, be shown, from actual observation, to have effected the entire change in any length of time of any portion of the Caucasian race into the Ethiopian, nor, on the other hand, of the Ethiopian into the Caucasian. It is objected, farther, that the peculiarities of the principal varieties of man existed in the early history of the race. This appears in relation to the Ethiopian variety in the figures found on Egyptian monuments. These show that the peculiarities of the negro race were as strongly marked nearly 5,000 years ago as they are now. This fixedness of character under such a variety of influences continued so long, it is claimed, indicates that the peculiarities were original, and not acquired.

580. In reply to both of these objections, I will call your attention to a general fact, which I deem to be very significant in its bearing upon the great point at issue. It is the fact that *when a variety is formed by any influences, either among plants or animals, it is apt to remain in spite of opposing influences.* It seems to be easier by far to produce a variety, than to bring it back to the character of the original from which it came.

Domestication has been continually producing varieties in the animals that man has so largely appropriated to his service, and the varieties once produced, commonly remain. And the same thing is seen in the varieties resulting from the same class of influences so continually in the human race. It is matter of common observation that family and national peculiarities are apt to be perpetuated. And it is not merely from a continuance of the causes from which they result, for they are apt to remain even when strong counteracting influences are brought to bear upon them. Now the causes which tend to produce varieties in the human race acted of course at the first, and were competent to produce the most prominent varieties during the first ages of the race. And the tendency to fixedness, which we see exemplified in so many ways in the varieties of both plants and animals, is sufficient to account for the perpetuation of such marked characteristics as those of the Ethiopian and the Caucasian.

581. The analogy then which is thus observed between man and the domesticated animals is a much clearer and stronger one, than that which Professor Agassis has attempted to make out between man and animals generally in regard to zoological districts. And the inference is a legitimate one, that the same influences, that we see produce varieties in domesticated animals, are competent to produce the varieties in the human race, which are even less marked than some of those which we see in animals. Varieties are produced more readily and in greater numbers in animals than in man, probably because they have less power of resisting influences that act upon them. The varieties of some of the domesticated animals are very numerous.

582. The analogy drawn between man and animals in regard to zoological districts is weakened by the consideration, that there was no necessity for man's being created in different localities, because he can migrate so easily from one country to another. The necessity existed in regard to plants and animals, but not to the same extent in all. Migration is easier in the case of some than in the case of others. And this difference seems to have been acted upon by the Creator. Accordingly, the evidence is quite conclusive, that those animals which have been so universally appropriated by man to his service, have been diffused from central points and have gone with man, instead of being created in many localities. This being the case, it is hardly to be supposed that man, who is capable, through his ingenuity, and skill, and daring, of going every

where, would be unnecessarily created in different pairs at different points on the earth's surface.

583. But suppose that in view of all the evidence we should come to the conclusion, that the climatic and other influences are not the sole causes of the differences in the races, are we of course driven to the admission that, as Agassis and others teach, there must have been created at the first, several, we know not how many different pairs in different localities? By no means. We are not to forget that the Creator, besides using influences of which we have no knowledge, (which he is continually doing,) can effect new combinations of the causes already existing, or introduce into operation entirely new causes. That he is from time to time evolving new results in one or the other of these ways, or both of them, is manifest. The very common notion, that at the creation all the causes which have produced all the phenomena that have been observed to the present time, were then set in operation, and have been left to work out their results, seems to be contradicted by many facts. Most of the causes then set in operation, it is true, have been at work ever since. Unless this were so, nature would not exhibit the regularity which it now does, and calculations could not be made with such definiteness as to its processes from knowledge gained by experience. But changes and irregularities sometimes occur which must have been the result of new causes. I shall allude to but a few examples.

584. The age of man before the flood was much greater than it has been since. A change was effected at that period. It was not a mere arbitrary change, but such a change in the very character of the human system, that its capability of resisting the tendency to decline was greatly reduced in the period of its continuance. It was not a change resulting from the influence of deteriorating causes, for in that case it would have been less suddenly induced. To effect this change some new causes must clearly have been brought to bear upon the system, making it in the post-diluvian a different system in some important respects from what it was in the ante-diluvian. Take a fact of a different kind, indicating a similar change of agency. New diseases from time to time appear. This could not occur without either entirely new causes, or new combinations of elements heretofore existing. That very definitely marked disease, the small pox, we have the best of evidence, was not known to the ancients, and is comparatively a modern disease. It is impossible to conceive of its being introduced without some new cause of a

very definite character. Take now another fact of a widely different kind from either of those to which I have alluded. The earth is marked all over with signs of great convulsions that have occurred since its first creation. It has been supposed till recently that these signs all refer to that great event described in the Bible, the Deluge of Noah; but geological researches have demonstrated pretty clearly that they point in part at least to other previous convulsions. Now these convulsions are not to be reckoned as a part of the regular order of nature. They could not have resulted from the ordinary causes that act continuously. New causes must have been introduced at the time, to produce these unwonted results.

585. It matters not to the argument above indicated, whether the new results that are occasionally developed, come from a direct agency at the time, or come from a chain of causes set in operation a long time before. The results are new results, and come from causes or combinations of causes, which differ from those that have produced the ordinary and regular results which we witness from day to day or from year to year.

586. Now in like manner can we suppose, if it be necessary, that the Creator produced the varieties of the human race, by adding other and new causes to the ordinary influences to which man is subjected. This is a much more probable supposition than that of the advocates of the multiple origin of the race. For besides accounting satisfactorily for the facts, and at the same time being consistent with the record in Genesis, it is more clearly supported by analogical facts than the supposition, (for it is a mere supposition,) that the human race was created in different localities. And farther, this supposition avoids difficulties which attend the other. For, if we suppose that the race came from different pairs, it would be difficult to decide how many pairs there were. Such are the variations of the race in different localities that there would be much disagreement as to the number of the representative pairs, and their distinguishing characteristics.

587. But it may perhaps be said in objection, that I am supposing a miraculous interposition. Whether it may rightly be termed such I will not stop to consider, but will merely remark, that it is just such an interposition, or rather, direct agency, as is affirmed by the advocates of a multiple creation, *differing from it only in the time of its occurrence.* They suppose the direct agency of God to be put forth in creation at different points, whether at different times they do not say, and this is

really quite immaterial; and I suppose the same direct agency to be put forth, but in a less marked manner, to produce a change in what has been already created. In supposing the direct agency of the Deity at all, we go beyond mere physics; and he surely has the power to put forth this agency at such times as he pleases.*

588. But the supposition made above is not in my view needed. I believe that the regular, continuous, natural causes, which have ever operated upon man, have been competent to produce all the varieties of the race. And I only suggest this supposition, as a consideration for those who fail to see that these causes have been thus competent; and I claim that it is a more probable supposition than the one offered by Agassis and others to meet the difficulty in the minds of such persons.

589. Thus far I have treated this subject chiefly as one of natural history and physiology. But is the testimony of the Bible not to be received as a part of the evidence? Is the question to be decided wholly on considerations and facts drawn from natural history and physiology? This seems to be the view of some naturalists, though the great majority of them are disposed to admit the statements of Scripture as evidence. It is true that the Bible does not purport to be a philosophical book. Its language is based upon the principles of common and not scientific usage, and is so to be interpreted. And it should be thus interpreted in relation to the subject before us. Its statements on this subject are of the most explicit character. It purports to give an account of the origin of the race, and portions of its history. It ascribes the corrupt character of the race to a fallen parentage. This connection of the general corruption of the race with the fall of its original pair, however divines and philosophers may differ in accounting for it, is recognized as a fact throughout the whole book of revelation. The testimony is definite, and is not to be mistaken. The question is, whether it be valid testimony. And if the Scriptural record be established, as it is abundantly, by both

* There seems to be in the minds of some naturalists a great reluctance to admit at all the direct agency of the Creator, whether it be exerted in consonance with the order of nature which he has established, or miraculously in opposition to it. And they would smile skeptically at what they would deem the simplicity or superstition of Hugh Miller, in referring some narrow escapes which he has had, in pursuing his geological researches, to a particular Providence. The relation of the agency of the great First Cause to second causes, it is true, is a mysterious subject; but it implies no disposition to fathom what is unfathomable if we assert that the facts are far from warranting us in the belief, that this agency has not been exerted since the period of the creation, but confined itself to that time.

internal and coincident evidence, its testimony in regard to the origin of the race is to be received by scientific men. It can not be set aside by any mere presumptive and analogical evidence drawn from physiology and natural history. If actual facts be proved inconsistent with the Mosaic history, as properly interpreted, they will of course bring discredit upon that history. No immunity against a strict investigation is to be claimed for the Bible. But there is no fear of such an issue; and it is to be remembered that mere analogies are not facts, and are not to be deemed as having much force, especially when there is a question in regard to their value in comparison with other analogies that point to an opposite conclusion.

586. If the account given in Genesis be a correct account, as is generally allowed by the advocates of the multiple origin of man, and if, as they claim, it is the account of the origin of only one branch of the race, while other pairs were created in other parts of the world, they are driven by the facts in the case to this alternative. Either other pairs were created with an original corrupt nature, or they were created innocent as Adam and Eve were, and then were tempted in a similar manner and with a similar result. To claim that the other pairs were made so like Adam and Eve as to constitute with them one species, alike physically, intellectually and morally, without taking either of the suppositions just given, is to admit the truth of only a small portion of the Mosaic account, and is also inconsistent with the existence of the great acknowledged fact of the general corruption of the race. So that it is evident that the unity of the race, and the truth of the Mosaic history, must stand or fall together. And it is not the truth of this history merely that is involved in this question, but the truth of the Bible as a whole. For the corruption of the race, which the Bible seeks to remove, as before remarked, is throughout this book distinctly referred to the fall of man as recorded in the Mosaic history as its origin. The *main facts* of that record are recognized as true by the whole scope of the Bible, whatever may be thought of the minute particulars of the narration. It matters not then, you will observe, to the argument, whether the Mosaic account be received as true in all its minutiæ, or whether it be considered, as it is by some, as a mere myth. For the argument is based upon the recognition by the rest of the Bible of the main facts contained in the history. And if it be a myth or fable, it must be based upon these facts, or, in other words, it is these facts that it is the object of this myth to convey.

587. I have thus presented a summary (for it necessarily is a mere summary) of what I deem to be the proper view of this subject. In doing so, I have left out many facts and considerations which are important, if we intend to go into a full and thorough investigation. I have selected for your consideration those points which are most prominent and important. I have attempted to indicate as clearly as I can the value of the different prominent arguments, that have been advanced on both sides of the question. And from the views and facts presented I think it very evident, that the true interpretation of the presumptive evidence, drawn from natural history and physiology, is entirely in accordance with the teaching of the Bible, viz., that God "made of one blood all the nations of men for to dwell on the face of the earth." We are all one brotherhood. And, therefore, however debased our fellow man may be—to whatever degree of degradation the unrestrained corruption of his nature may have brought him—we are to look upon him as containing the elements of that moral and intellectual elevation which is attained by the most gifted of men. It is this view of the subject that imparts dignity, and interest, and hope, to all philanthropic efforts to raise man from the moral, intellectual, and physical degradation, to which sin has reduced him.

588. Although there are perhaps none at the present time who distinctly advocate the doctrine, that the lower races of men, as they are termed, are half way between man and such animals as the monkey and ourang-outang, yet there is in some minds an indefinite partial admission of this idea. There is a disposition in some naturalists to make the most of any resemblances found between these races and animals. The attempt has been sometimes made to show, that there is a decided resemblance between the form of the Ethiopian and that of the monkey tribe. But it has always failed. It has been said that the arm of the negro is longer than that of the Caucasian, and that in this respect he approaches to animals of this class. But the difference is so slight that the analogy fails entirely. And besides, the hand of the negro, the most important part of the upper extremity, bears no manner of resemblance to the imperfect hand of the monkey, but is essentially like that of the European. It has been said, too, that the brain of the negro is like that of the monkey. The brain in any race or family of men that are debased and ignorant is smaller than in the elevated, and in this respect alone does it approach to that of the monkey and other higher orders of animals. And, as I have

before said, there are certain mental characteristics in the most debased which link them to the most exalted of our race, creating an "impassable chasm" between them and the most intelligent of animals.

CHAPTER XX.

LIFE AND DEATH.

589. Life is very commonly spoken of as being one thing, although its manifestations are exceedingly various in their character. In the simplest growths that we see, both in the vegetable and the animal kingdoms, the operations of life are in some respects very different from the complicated processes, that we witness in the human structure, which has been the subject of your study in this book. And yet, as you have seen in the Chapter on Cell-Life, life in these apparently opposite cases is essentially the same. It is the same in its origin. It begins always in a single cell, whether the living being is to be minute or monstrous, simple or complex, a plant or an animal, a creature of a day, or a being destined to immortality. Why it is that from a simple cell the vital force, as it is termed, can evolve such a range of diversified results as we see in all animated nature, is one of the great mysteries of the Creator. As we see in the spring time a bud upon a tree unfold itself gradually, and develop to us successively leaves and flowers and fruit, it fills us with wonder, when we reflect how much has come from that little bud; but when we go farther, and think of the whole tree as having come from a single cell, so small that it can be seen only by the microscope, the mystery appears passing wonderful. And it is a still greater mystery, when a complicated animal organization is looked at as having been developed by the vital force, alike with all other living things, through a single cell as its origin.

590. Life is not only always the same in its origin, but it continues essentially the same in its processes. All the various forms which it produces, both in the vegetable and animal world, are built and kept in repair by cells. All the functions, too, are carried on through the same agency. The secretions

and excretions, as you saw in § 201, are effected by constant successive creations of numberless cells. Even the intellectual operations in the mind of man are dependent upon cells so long as the mind is connected with the body. In thinking, as well as in muscular motion, cells are worn out, and must be replaced by other cells, which are continually supplied by the vital force.

591. Life being thus wonderful in its operations, the inquiry arises, what can this mysterious agent be. With curious eye we watch its workings, but although we can learn some of its laws, its nature eludes our search. Then pressing the microscope into our service, we trace it back to its hiding place in a minute round cell containing a fluid; but simple as this prison is in which it is confined, it is more of a mystery than ever. The vital force, which begins here, and, enlarging more and more the sphere of its operations, developes gradually the simple or the complicated living form, as the case may be, has been classed by some with other forces, the nature of which we do not understand, as heat, light, and electricity. But it differs from them entirely in some important points. While they act in connection with matter generally, both organized and unorganized, vital force is only seen acting in organized substances. While they diffuse themselves through all kinds of matter with more or less rapidity, the vital force has no power of diffusion, but is confined within certain limits. These limits differ in the different living substances. The vital force has the power of appropriating matter to itself within these limits. It does this by assimilation, as described in § 10. It has then the power of extension to a limited degree; while the other forces mentioned have the power of diffusion, in some respects limitless.

592. Another difference is this. While these forces, light, heat, and electricity, are lessened in power by being diffused, vital force is not lessened by extension. Heat, for example, if diffused is lessened at the point of its diffusion; but life is as energetic at its starting point after its extension as before, and even more so. It is, so to speak, self-generating, while the other forces are mere products. The vital force stands peculiarly alone in this respect. The effects too, which this force produces, as it lays common matter under contribution, and fashions it in such diversified forms, have an infinitely wider range of variety than the effects of the other forces.

593. We can thus trace the differences between the vital force or principle and other forces, but we cannot, as I have before said, discern its nature. We know not whether it be one thing.

It is convenient to speak of it as being so. But we know not but that it may be a compound of endowments, or tendencies imparted to matter, and varying with the various forms of living substances. Some have supposed that the vital principle resides chiefly in the blood, and that this is the meaning of the passage in the Bible, "the life of the flesh is the blood." That the blood has some vital properties is certainly true. These properties are communicated to it as it is made from the food, and fit it to be the material for the construction and repair of the organization. And it is simply the fact, that the blood is the common material out of which all the diversified parts of the living structure are made, that is recognized in the language of Scripture on this subject. The same fact is embodied in another form in the remark of the French physiologist, that the blood is *chair coulante*, or running flesh.

594. When the vital force appropriates to itself common matter in assimilation, it takes it away in part from the operation of certain forces which have had entire control over it. As long as it is common dead matter, it is wholly subject to the laws of mechanics, and of chemical action. But when it becomes organized living matter, the laws of life take possession of it. The laws of chemistry and mechanics are not, it is true, annulled in relation to it. They still exert their influence, but under the control of vital laws. The force of gravity acts continually upon the body; but the living muscles are much of the time acting in direct opposition to it. The blood circulates on hydraulic principles; but the vital force furnishes the motive power, and keeps the blood from becoming solid and stopping up its channels. Chemical changes are going on in the stomach, the lungs, and at every point in the capillary circulation; but they are modified, controlled, by the vital principle, and are properly termed chemico-vital processes.

595. The human body is made of materials that are exceedingly prone to chemical decomposition, and the degree of heat which is maintained is such as to favor this result; but the vital force not only holds the chemistry of the system in abeyance, but even presses it into its service. When life is destroyed, the laws of chemistry assume their full sway, and the process of decay begins. The very agencies which served, while under the control of the vital principle, to maintain the living organization, now acting alone run riot, and work its destruction. Thus, that powerful agent, heat, existing in the body at the point of 98°, is necessary to the carrying on of the processes of

life; but let life be destroyed, and the maintenance of this degree of heat would ensure a very rapid putrefaction. So too, a degree of heat which would rapidly putrefy a dead egg by quickening the chemical changes, would actively stimulate in a living egg those curious vital processes that produce at length the bird. During incubation the egg of the hen is kept for three weeks at a heat of 105°, and yet when the chicken is hatched all of the yolk that is left is unchanged. A dead egg would soon putrefy under such a temperature.

596. The vital force exhibits its controlling power in an extraordinary manner in connection with that great force of nature to which I have just referred. Heat is very diffusive, and is exceedingly liable to change from varying circumstances. And yet the vital force maintains the heat of the body quite uniformly at one point, although the agencies which tend to vary it are very numerous and effective. The production of heat in the system is a chemical operation, but the vital principle regulates the quantity in the body very accurately, by providing for its escape in various ways, and perhaps by curtailing in some measure its production.

597. Continual changes are effected by the vital force in every part of the body. In one sense death may be said to be taking place constantly, while life is as constantly generated, as the useless particles are separated and taken away, and the new ones are deposited in their place. While these changes are going on the vital force so operates as to maintain the peculiar shape and plan of every part, even during its growth. And as we look abroad over all the diversified forms of animated nature, the accuracy with which this force works in the prescribed mould of each is very wonderful. This point I have commented upon in the first chapter, page 18, and will not dwell upon it here.

598. While the vital force is in action there is constant change; but sometimes it is dormant. A seed in its quiescent state has life in it, ready to be waked into action by the proper excitants, air, warmth, and moisture. Seeds that were found in the excavations of Pompeii have shown that they retained their life during all this time, by shooting forth their germs as soon as they were exposed to these natural excitants of their growth. One of the most interesting cases of this kind is related by Dr. Lindley. "I have now before me," he says, "three plants of Raspberries, which have been raised in the gardens of the Horticultural Society, from seeds taken from the stomach of a man,

whose skeleton was found thirty feet below the surface of the earth, at the bottom of a burrow which was opened near Dorchester. He had been buried with some coin of the Emperor Hadrian, and it is probable, therefore, that the seeds were sixteen or seventeen hundred years old."

599. A similar dormant condition of the vital force exists in a greater or less degree, as you saw in § 158, in the state of hibernation. So also, in cold climates, life is throughout almost the whole vegetable world dormant during the period of winter, to wake to greater energy from the stimulating warmth of spring. In the human body, with the exception of some few very rare cases, life is always in an active state. Some portions, however, of the system are a part of the time dormant for the purpose of rest and repair. The brain and the muscles sleep; but during their sleep life is busy in the formative vessels, repairing their energies, and we may say, their textures also, which have been wasted by their labor. I will not dwell longer upon this interesting subject, but in leaving it I remark, that it is a very wonderful attribute of the vital force that it can, as in the case of the hibernating warm blooded animals, stop all its active operations, without damage to the machinery of life, and with such facility resign itself into a state of temporary inactivity.

600. The most mysterious of all the circumstances in regard to the vital force is its connection in man with the immortal soul. The life and the soul are so intimately connected that some have considered them to be the same. But they are two distinct forces. They are in some measure indeed antagonistic to each other. For the soul, in using the machinery of the nerves and muscles occasions a wear and tear of the structure, which it is the office of life with its numberless cell-laboratories to repair. The soul and the vital principle are both present in all parts of the system, but not in the same sense. The vital principle is seen equally at work every where. It has no great central organ from which it sends forth its influence. But the soul is especially connected with the brain, and by means of the complicated nervous connections of this organ, it affects and is affected by all parts of the system. Its influence is thus an all pervading one. Every point of the living organization has thus a sort of telegraphic communication with the immaterial soul.

601. But there is another view of this connection of the soul and the vital principle. The soul is developed in and with the

living structure. It is not created by itself and put into the body as a tenant. Its powers are developed while the vital force developes the powers of the physical organization. The two processes go on together. Nay more, the development of the soul is in a measure dependent upon the development of the body. The vital force exerts a manifest influence upon the soul's growth. As it prepares the organs for the use of the soul—those organs by which it acquires knowledge from without, and thus procures the stimulus and even the material for its growth—whenever the vital force fails to construct these organs properly, the powers of the soul are not well developed. This we see exemplified in the idiot. In this intimate connection of the soul with life we find a great mystery. Life, a force belonging to mere matter, an endowment of it, or a compound of its endowments—life, that builds up all organized substances, the humblest and simplest vegetable growth, as well as that most complex of all living structures, man—life, that so soon perishes in the noblest of its works that it is likened to the dissolving vapor—is made by the Creator an agent in developing an immaterial principle or being, that is to survive the dissolution of the structure in which it is generated, and is to live forever. Strange that the immortal should be thus produced in the mortal—that the unchangeable and imperishable soul should be thus developed in such intimate connection with the changeable and perishable body. It is a mystery which we cannot fathom.

602. The vital force, that is so busy in building and repairing so long as it lasts, has in all cases its natural limit; and in the case of the human system it seldom fully reaches this limit. The diversified, and complicated, and beautiful structures which it evolves, if saved from accident till the natural period of decline comes, lose their vigor and beauty, and at length die and are given up to the action of the common laws of chemistry, which the vital force has so long resisted and controlled. The structures then decay, and the particles are dissipated, perhaps to be united again to other structures.

603. The death of the body is not ordinarily complete at the moment when what we term death occurs. Though as a whole, as a system of organs, the operations of life are at an end, yet there is some degree of life in some parts, and there may be in all parts of the body. The beard and nails even, may grow. Some of the organs may secrete their fluids—the liver its bile, and the stomach its gastric juice. Some of the

properties of life, too, manifestly still remain. The irritability of the muscles, which is strictly a vital property, as it never belongs to common dead matter, still appears on the application of excitants. It was the contraction of the muscles in the leg of a dead frog on the accidental application of a stimulus, that led Galvani to his grand discovery. And it is through this vital property that the culprit who has been hung can be galvanized into apparent life. Death then may be said to be of two kinds—*systemic*, that is, the death of the body as a whole, a system of organs—and *molecular*, that is, the death of the individual molecules or particles which compose the body. Death can be said to be complete only when the laws of life have resigned their power over these molecules, and the laws of purely chemical action have taken their place. When this change occurs, the process of decay, which is strictly a chemical process, begins.

604. It will be interesting to notice here the modes in which systemic death occurs. There are three great systems in the body, each of which is immediately essential to the continuance of life—the system of the circulation, the respiratory system, and the nervous system. And we may speak of death as beginning in any one of these systems when the cause of death acts primarily upon it. I will notice some examples under each head.

605. If a large quantity of blood be lost, so large as to result fatally, death in this case obviously begins in the *circulation.* The heart not being supplied with the quantity of blood that usually flows through it, becomes more and more feeble in its action, till it at length ceases to beat. When a large aneurism bursts, it is the sudden drain from the circulation that destroys life.

606. Any thing which to any great extent prevents the air from entering the lungs may cause death to begin in the *respiratory* system. This may be done by three classes of causes. 1st. Causes that act upon the large air passages. Examples of this class of causes are strangling, smothering, drowning, &c. In croup the principal cause of death is the prevention of the free passage of air through the windpipe into the lungs. 2d. Causes which act upon the walls of the chest. If a bank of earth fall upon a man, though it leave his head clear, so that the air passages are unobstructed, he cannot breathe, because his chest is held as if in a vice. A man came near dying from this cause, who was having a cast taken of the upper part of

his body. If the muscles of respiration were to be paralyzed, death would ensue, just as it does when they are prevented from acting by other causes. 3rd. Causes acting upon the lungs. Disease may occasion an amount of obstruction in the very substance of the lungs sufficient to cause death. It does so by preventing the introduction of the air into the minute air vessels, where the air revivifies the blood. The obstruction is just as effectual in this case as it is where it occurs in the large air passages.

607. When death occurs from a blow upon the head as the immediate result of the shock, we have an example of death beginning in the *nervous* system. But the cause may act upon this system in some other quarter. A blow at the pit of the stomach, for example, may so shock the whole nervous system as to stop at once the operations of life. Some poisons, too, as opium, destroy life by their influence upon this system. Very extensive burns give a shock to the nerves from which they do not rally. The same can be said of other injuries when there is no recovery from the first shock. Powerful medicines, improperly given in cases of disease disposed to prostration, may depress the nervous system to a point from which it may never revive. Cold destroys life mostly by the benumbing, paralyzing influence which it exerts upon the nerves.

608. Though we thus classify the modes of death, in the great majority of cases death is a complex event, resulting from a concurrence of causes. It is so even when the disease is not of a complicated character. Take, for example, a case of pure uncomplicated consumption, in which all the organs but the lungs are in a healthy state to the end. The whole system becomes at length exhausted by the disease. If this exhaustion alone be the cause of death, then we may say that it is an example of death beginning in the nervous system. But if the obstruction in the lungs to the admission of air in the air-cells be the cause, it is a case of death beginning in the respiratory system. Generally in such cases death results from the two causes combined, and it is often difficult to determine which is the more prominent cause.

609. The signs of death are so clear that there is, with very few exceptions, no mistake in regard to the occurrence of the event. The stories that are related about burying alive are most of them unfounded. The apprehensions created by them in the minds of some persons have led them to insist, that no body ought to be committed to the grave, till the most infalli-

ble sign of death, putrefaction, has appeared. That we should wait for the appearance of this sign in all cases in which there is a shadow of doubt, I will allow. But the cases are exceedingly rare in which we cannot determine the reality of death long before this sign shows itself. Our decision is not made up, it must be observed, merely from the signs of death. All the circumstances of the case are taken into view—the disease, its progress, its symptoms, and the events of the last hours of the patient. With this evidence before us, we absolutely know, in all ordinary cases, that death has occurred when the respiration and the circulation have ceased. And in the exceedingly few cases in which there is any reason to doubt on that point, there is always something which will attract the attention and excite the curiosity of some one, unless there be stolid indifference and the most absolute lack of intelligence. In such cases there is always something strange—the circumstances attending the cessation of the respiration and circulation are singular, and the signs of death are not complete and in their proper order of succession. Whenever there is for these reasons any doubt as to the reality of the apparent death, the strictest watch should be maintained till the signs of commencing putrefaction appear. With this simple rule of prevention burying alive need never to occur.

610. The investigations of physiology, as you have seen, end with the death of the body. It can give us no light on the question as to what may be beyond this life. Although the physiologist studies the human structure not merely as an organization instinct with life, but also as the wonderful machinery through which a reasoning soul acts and is acted upon in this state of being, yet, as a physiologist, he knows not that the soul survives the death of the body. He knows not but that it is a mere endowment of matter, as life probably is, and so perishes in the hour of dissolution. He may indeed conjecture that such exalted faculties which are in this world susceptible of such high cultivation, instead of being destroyed with the body, are destined to still farther development in another state of existence. But what is mere conjecture to him as a Physiologist, is made fact to him as a Christian. The eye of his faith sees an immortal spirit rise from the dying body, and he realizes the truth of the sublime declaration, that "death is swallowed up of victory."